DHARAMPAL • *COLLECTED WRITINGS*

Volume I

INDIAN SCIENCE AND TECHNOLOGY IN THE EIGHTEENTH CENTURY

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Volume I
Indian Science and Technology in the Eighteenth Century

Volume II
Civil Disobedience in Indian Tradition

Volume III
The Beautiful Tree: Indigenous Indian Education
in the Eighteenth Century

Volume IV
Panchayat Raj and India's Polity

Volume V
Essays on Tradition, Recovery and Freedom

INDIAN SCIENCE AND TECHNOLOGY IN THE EIGHTEENTH CENTURY

Some contemporary European accounts

by
Dharampal

Other India Press
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By Dharampal

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An introduction to the
Collected Writings
of
Dharampal

Preface

Making History

By Claude Alvares

My encounter with the amazing historical work of Dharampal came about in 1976 in a most unexpected place: a library in Holland. I was at that time investigating material for a Ph.D dissertation, part of which dealt with the history of Indian and Chinese science and technology.

While there was certainly no dearth of historical material and scholarly books as far as Chinese science and technology were concerned—largely due to the work of Dr Joseph Needham, reflected in his multi-volumed *Science and Civilisation in China*—in contrast, scholarly work on Indian science and technology seemed to be almost non-existent. What was available seemed rudimentary, poor, unimaginative, wooden, more filled with philosophy and legend than fact.

Desperate and depressed, I wandered through the portals of every possible library in Holland trying to lay my hands on anything I could find. The irony of looking for material on Indian science and technology in Holland should not be missed. However, I was doing a Ph.D. there and had very little choice.

Then one morning, I walked into the South East Asia Institute on an Amsterdam street and found a book called *Indian Science and Technology in the Eighteenth Century* on the shelf. I took it down, curious. It was by a person named Dharampal whom I had not heard of before as a person or scholar active in that area of research. I took the book home and devoured it the same day. It altered my perception of India forever.

Now, more than twenty years later, I know that the book appears to have had a similarly electrifying effect on thousands of others who were fortunate to get a copy of it. It spawned a generation of Indians which was happy to see India thereafter quite differently from the images with which it had been brought up in school, particularly English medium school.

The book also provided a firm anchor for the section of my dissertation dealing with Indian science and technology. The dissertation was eventually published in 1979 with the rather academic title: *Homo Faber: Technology and Culture in India, China and the West: 1500 to the Present Day*. (*Reissued as *Decolonising History: Technology and Culture in India, China and the West: 1500 to the Present Day,* Other India Press, 1997.)

The same year (1976), a friend of mine from Orissa dropped in at our flat in Amsterdam. I mentioned Dharampal to him. Astonishing to relate, he turned out to be a friend of Dharampal and even told me where he lived. Next door, he said, in London. He also had Dharampal's telephone number. The following week, we took a flight to London and I met Dharampal for the first time in my life. His family was with him at the time: his wife, Phyllis, his two daughters, Gita and Roswita, and his son, David.

The meeting initiated a relationship that has persisted till the present moment. Today I am happy to head a publishing house that is bringing out his *Collected Writings*.

I myself returned to India in 1977. Stranger events followed thereafter.

In 1980, I was called to Chennai to join a civil liberties team probing the killing of political activists in fake police encounters in North Arcot district in Tamilnadu. Predictably, our team was beaten up by a mob set up by the police. On our return to Chennai, where we decided to hold a press conference, we were put up at the MLA hostel. While passing by one of the rooms, whom should I see sitting there but Dharampal himself! I had to rush to the press meeting thereafter.

Before the press could arrive, however, two or three young strangers arrived to meet me. They said they were from the Patriotic and People-Oriented Science and Technology (PPST) group which had members and sympathisers in both Kanpur and Madras IITs. They wanted to sit with me and discuss my book, *Homo Faber* (the Indian edition had just been brought out by Allied Publishers then). They also wanted more information about Dharampal, whose work they were coming across for the first time in *Homo Faber.* Why do you want to talk to me, I asked them, when you can very well meet Dharampal himself! They were astonished. Dharampal? Here in Madras? When I told them where I had found him, they made a bee-line for the MLA hostel.

That encounter initiated a long, fruitful and creative association between Dharampal and the PPST which has also persisted, with some ups and downs, to the present day. For a few years, the PPST brought out a journal called the *PPST Bulletin*. In it, Dharampal and his work occupied pride of place. During this period, in fact, members of the PPST Group produced some of the finest articles ever written and published on the subjects of Indian science, culture, technology, and the relevance of Western science and technology to Indian society. Some members of the PPST later spent a considerable amount of time and energy working on the Chengalpattu data which often recurs in Dharampal's writings.

Today, Dharampal's work is quite extensively known, far beyond the PPST Group, not just among intellectuals and university professors, but also among religious leaders including swamis and Jain monks, politicians and activists. One of the most impressive off-shoots of his research has been the organisation of the bi-annual Congress on Traditional Sciences and Technologies. Three such Congresses, organised by the PPST and institutions like the IITs, have so far been held, generating an impressive wealth of primary material. Dharampal himself has been invited to deliver lectures at several institutions within India and abroad. (Some of these lectures can be found in Volume V of the *Collected Writings*.)

The general effect of Dharampal's work among the public at large has been intensely liberating. However, conventional Indian historians, particularly the class that has passed out of Oxbridge, have seen his work as a clear threat to doctrines blindly and mechanically propagated and taught by them for decades. Dharampal never trained to be a historian. If he had, he would have, like them, missed the wood for the trees. Despite having worked in the area now for more than four decades, he remains the quintessential layman, always tentative about his findings, rarely writing with any flourish. Certainly, he does not manifest the kind of certainty that is readily available to individuals who have drunk unquestioningly at the feet of English historians, gulping down not only their 'facts' but their assumptions as well. But to him goes the formidable achievement of asking well entrenched historians probing questions they are hard put to answer, like how come they arrived so readily, with so little evidence, at the conclusion that Indians were technologically primitive or, more generally, how were they unable to discover the historical documents that he, without similar training, had stumbled on so easily.

Dharampal's unmaking of the English-generated history of Indian society has in fact created a serious enough gap today in the discipline. The legitimacy of English or colonial dominated perceptions and biases about Indian society has been grievously undermined, but the academic tradition has been unable to take up the challenge of generating an organised indigenous view to take its place. The materials for a far more authentic history of science and technology in India are indeed now available as a result of his pioneering work, but the competent scholar who can handle it all in one neat canvas has yet to arrive. One recent new work that should be mentioned in this connection is Helaine Selin's *Encyclopaedia of Non-Western Science, Technology and Medicine* (Kluwer, Holland) which indeed takes note of Dharampal's findings. Till such time as the challenge is taken up, however, we will continue to replicate, uncritically, in the minds of generation after generation, the British (or European) sponsored view of Indian society and its institutions. How can any society survive, let alone create, on the basis of borrowed images of itself?

Dharampal's own description of his initiation into Indian historiography is so fascinating it must be recounted in some detail. Soon after he got associated with the Quit India movement in 1942, he became attracted to the idea of the village community. Perhaps this was partly due to his being with Mirabehn in a small ashram community in a rural area in the Roorkee-Haridwar region from 1944 onwards. But when in 1948, he heard of the Jewish Kibbutzim in Palestine, this interest was evoked again and he visited them in late 1949 for some two weeks. He came away from the visit, however, with the feeling that the Kibbutzim model was not something that could be replicated in India. Later, along with other friends, he did attempt to launch a small village near Rishikesh in which all families had an equal share of the land, etc. The village, however, could not mould itself into a community: it lacked homogeneity. It also had practically no resources at all when it began. Later, in 1960, Dharampal got to know of village communities in Rajasthan which had *Bees Biswa* village panchayats, and some *Sasana* villages near Jagannath Puri in Orissa which were established some 700 years earlier and were still prosperous and functional in the early 1960s.

An encounter which affected Dharampal greatly in this context is best recounted here in his own words:

Around 1960, I was travelling from Gwalior to Delhi by a day train, a 6 or 7 hour journey in a 3rd class compartment when I met a group of people and I think in a way that meeting gave me a view of India, the larger India.

The train was crowded. Some people however made a place for me. And there was this group of people, about twelve of them, some three or four women and seven or eight men. I asked them where they were coming from. They said that they had been on a pilgrimage, three months long, up to Rameshwaram, among other places. They came from two different villages north of Lucknow. They had various bundles of things and some earthen pots with them.

I asked, what did they have in those pots. They said that they had taken their own food from home. They had taken all the necessities for their food—atta, ghee, sugar—with them, and some amounts of these were still left over. The women didn't seem to mind much people trampling over them in the crowded compartment, but they did feel unhappy if someone touched their bundles and pots of food with their feet.

And then I said they must all be from one jati, from a single caste group. They said, 'No, no! We are not from one jati—we are from several jatis.' I said, how could that be? They said that there was no jati on a yatra—not on a pilgrimage. I didn't know that. I was around 38 years old, and like many others in this country who know little about the ways of the ordinary Indian—the peasants, artisans and other village folks.

And then I said, 'Did you go to Madras? Did you go to Bombay?' 'Yes! We passed through those places.' 'Did you see anything there?' 'No, we did not have any time!' It went on like that. I mentioned various important places of modern India. They had passed through most, but had not cared to visit any.

Then I said, 'You are going to Delhi now?' 'Yes!' 'You will stop in Delhi?' 'No, we only have to change trains there. We're going to Haridwar!' I said, 'This is the capital of free India. Won't you see it?' I meant it. I was not joking. They said, 'No! We don't have time. May be some other day. Not now. We have to go to Haridwar. And then we have to get back home.'

> We talked for perhaps 5 or 6 hours. At the end of it I began to wonder, who is going to look after this India? What India are we talking about? This India, the glorious India of the modern age, built by Jawaharlal Nehru and other people, these modern temples, universities, places of scholarship! For whom are we building them? Those people on their pilgrimage were not interested in any of this. And they were representative of India. More representative of India than Pandit Jawaharlal Nehru ever was. Or I and most of us could ever be.

The encounter shook Dharampal then, as much as the memory of it bothers him even today. This particular experience, more than any other, drove him to look for the causes of the profound alienation of India's new leaders from the preoccupations of the common people and to investigate whether this had always been so.

Similarly, fascinated by the largely intact and functioning *Bees Biswa* and *Sasana* village communities, he wished to know what it was that had kept these aspects of Indian civilisation so far alive and ticking (in contrast to some of the disintegrated and pauperised communities we encounter in the present). He assumed that if the basis of these hitherto vibrant communities were understood, it might assist Indian society—particularly its intellectuals and political leaders—to divest itself of its present state of depression and disinterest with its surroundings and perhaps become lively again. The inquiry had to focus on how India had functioned before the onset of the debilitating British and European dominance. When he began, he had no clear direction in which to look. Even after he had found what he was looking for, the utter significance of it would dawn on him only later.

It is important for the reader to know that till about 1964, Dharampal merely had a layman's knowledge of archives and the records and material they generally held. His first acquaintance with the archival record on India began at Chennai (previously Madras) during 1964-65 but expanded and deepened over the years. He discovered that most of the material dated from around 1700 A.D. and owed its creation largely to British needs, even when these archives held some Indian language materials on paper or palm leaves. (The Portuguese, the Dutch, the French, and the various European Christian as well as commercial institutions which began to come to India from the mid-16th century also maintained similar archives relating to their encounter with India but these were smaller.)

All this British archival material (some of which is presented or referred to in the *Collected Writings*) mostly dwells on certain aspects of India as seen and understood then by the British. The material falls broadly within three areas:

The first relates to descriptions of India, its physical landscape, the manners of its people in certain regions, their public life, festivals, cultural life and institutions, the nature and extent of Indian agricultural and industrial production, and Indian sciences and technologies.

The second pertains to the continuing British-Indian encounter, especially from around the British occupation of Arcot in 1748 to about 1858. Then the encounter is again visible from about 1875, and with its high and low spots, continues till 1947 when India got divided into India and Pakistan, and the British-created institutions and functions were taken over by their own governments.

The third begins with the unfolding of British designs and policy pertaining to India in Britain in the 1680s and thereafter, and their visible implementation and imposition on India from around 1750. The origins of these designs and policies remain mainly in Britain till the very end, while their implementation is in India, and in the areas governed in India's name from the China seas in the East to St. Helena in the West.

It would be helpful at this stage to know how this huge and very detailed archival record was indeed created. For this purpose, a little background relating to the governance of India during English colonial rule is absolutely necessary.

It is conventional doctrine (taught in most history books) that from 1600 to around 1748 the British East India Company (E.I.Co.) established itself largely in the coastal towns and cities of India, declared these places as fort towns and called them factories, i.e. store houses for trade, with the requisite military establishments. From 1748, the E.I.Co. is said to have gradually involved itself in the conquering of India and till 1858 at least was considered to be solely responsible for the plunder and violence associated with the conquest. We are further told that it is only because the British were disturbed by the company's misrule—which resulted in the great Indian Mutiny of 1857-58—

that they decided to establish direct rule in India and that the governance of India was placed under the charge of a British cabinet minister named the secretary of state for India, an arrangement that eventually continued till 1947.

It is true that an E.I.Co. was established in Britain through the grant of a charter in 1600, and that it had adventurers and plunderers in its ranks. But, according to Dharampal, it never altogether functioned on its own. From the beginning, the company had the full support of British naval forces in its expansion drive, and often of British state military forces as well. Also, from the beginning, the E.I.Co. contributed substantial sums (in millions of pounds sterling) to the British government treasury and also advanced amounts at low interest to the British state. From time to time, it received directions from British state authorities and at times certain of its affairs were placed under the charge of British naval commanders who received their instructions directly from the British King or the British Admiralty. It is these directions and communications that comprise the earlier archival records.

One such major case involving official supervision was the final British encounter with Admiral Kanohji Angrey of Maharashtra around 1754. The British state felt he was a great challenge to British expansion and had to be somehow eliminated. There would have been scores of such instances between 1600—when the E.I.Co. originated—and 1750, when it began to assume the role of a conqueror and sovereign.

From 1750 onwards, more and more instructions from the British were conveyed through various channels to the E.I.Co. After the British domination of Bengal from 1757 onwards, Robert Clive—a 'heaven born General' according to Lord Chatham, virtual ruler of the British then—wrote to Britain that India could only be governed directly by the British state and not by any company. This and other similar advice was deliberated upon for some years leading to the Regulating Act of 1773 by which the British state appointed the Governor General and his Council, and 11 years later, to the 1784 Act, which established a Board of Commissioners for the Affairs of India, with a President and 6 members, one of whom in the early stages was none other than the British Prime Minister. The Commissioners then were made the rulers of India. All instructions of any kind to any department of state in India, or to its three Presidencies, were cleared by them in detail (word by word, comma by comma). Once these were final, the job of the Court of the E.I. Co. was to send these to India under the signature of their Chairman and members.

Besides, a separate channel of communication was opened between the President of the Board of Commissioners and the British Governor General in India (as also with the Governors of the Presidencies), which at times even over-rode certain formal instructions conveyed through the company. The instructions in certain departments were prepared by the Board of Commissioners themselves, the signature of the Chairman of the Company obtained, and the matter sent to India from the Board's office itself. It is this arrangement which prevailed till 1858. The change in 1858 was in fact only a change in nomenclature: the President of the Board was now the Secretary of State for India. (Thus, the E.I.Co. as such became wholly redundant in the ruling of India, or areas in its vicinity i.e., from the China seas to St. Helena, from 1813 onwards, if not from much earlier. According to Dharampal, this clarification needs to sink deep not only into Indian minds, but, into the minds of the world historical community too.)

Thus, details of every occurrence in India which came to the notice of British authority had to be communicated, at least till 1858, to London in order to obtain instructions or the approval of London on the individual issue. The British archival record therefore informs us of each and every such event.

So, if one wanted to have knowledge in any detail of the society and life of India before British dominance, the obvious thing to do was to carefully peruse these British-generated archives. This Dharampal now did. He did not have much of an income. There was also a family to support. But notwithstanding all this, he became a regular visitor to the India Office and the British Museum. Photocopying required money. Oftentimes, old manuscripts could not be photocopied. So he copied them in long hand, page after page, millions of words, day after day. Thereafter, he would have the copied notes typed. He thus retrieved and accumulated thousands of pages of information from the archival record. When he returned to India, his most prized possession was these notes, which filled several large trunks and suitcases.

It is not that others had not consulted these very records before. Dozens had. They missed the overall picture largely because they saw the material in fragments, for a particular piece of research, over a month or a year or two. Dharampal, in contrast, gave it the benefit of decades. His mind retained every detail of what he read with uncanny sharpness. That is how he eventually got the whole picture.

This picture that emerged from the total archival record was nothing short of stunning. Contrary to what millions of us were taught in our school text-books, it indicated the existence of a functioning society, extremely competent in the arts and sciences of its day. Its interactive grasp over its immediate natural environment was undisputed; in fact, it demanded praise. This was reflected in both agricultural and industrial production. We know today that till around 1750, together with the Chinese, our areas were producing some 73% of the total world industrial production, and even till 1830, what both these economies produced still amounted to 60% of world industrial production. Even in a moderately fertile area like that of Chengalpattu (Tamilnadu), our paddy production in a substantial area of its lands around 1760-70 amounted to some 5-6 tons per hectare, which equals the production of paddy per hectare in present day Japan—the current world high. A vast educational set-up—based on a school in every village—looked after the requirements of learning of large masses of young people.

The most impressive feature of the set-up was the elaborate fiscal arrangements made for its upkeep in perpetuity, if required. From the gross produce, amounts were allocated by tradition for the upkeep of the system, from the engineers who looked after the irrigation tanks and channels to the police and school teachers. In technology, we produced steel that was superior to Sheffield steel. We also produced dyes, ships and literally hundreds of commodities.

As he recorded all this, Dharampal also saw how it was all being undermined, how the British in fact went about pulverising the Indian economy and society.

As he studied the sometimes fascinating, sometimes cruel record, practically every day, it held him as if bewitched. He found that the British successfully initiated an intricate system of widespread control and extortion, taking away as tax most of what the land produced, as well as the products of manufactures. He found it horrifying that this was often done at the point of the bayonet.

According to Dharampal, the British purpose in India, perhaps after long deliberation during the 17th century, was never to attempt on any scale the settlement of the people of Britain or Europe in India. It was felt that in most regions of India, because of its climate, temperature range, gifted, industrious and dense population, the settling of the people of Europe would serve little purpose.

Therefore the purpose was defined as bringing to Britain and Europe, surplus products of the varied industry of the people of India, and the taxes imposed on this industry. Such a proposal, in fact, was very clearly put forward around 1780 by Prof. Adam Ferguson of Edinburgh. Ferguson was a professor of moral philosophy. (Interestingly, he is also regarded as the founder of British sociology.)

While discussing the mode of governing India, Ferguson raised the question of the purpose of this governance. According to him, the aim was to transfer as much as possible of the wealth of India to Europe. And this task, according to him, could not directly be conducted by servants and institutions of the British state. They would be too bound by rules and state discipline to do justice to the task. The transfer of wealth to Europe, he felt, would generally require the bending and breaking of rules as no major extraction or extortion from the ruled could be effectively done through instruments of the state. He therefore felt that the direct governance of India should be in the hands of the servants of a body like the E.I. Co., where the servants could when needed disobey orders and rules. But the company should be controlled and supervised by a high-power body constituted by the state. It is this logic and arguments that eventually led to the formation of the Board of Commissioners for the Affairs of India in 1784.

Dharampal found that for long periods in the late 18th and the 19th centuries, the tax on land in many areas exceeded the total agricultural production of very fertile land. This was particularly so in the areas of the Madras Presidency (comprising current Tamilnadu, districts of coastal Andhra, some districts of Karnataka and Malabar). The consequences of the policy were easy to predict: in the Madras Presidency, one third of the most fertile land went out of cultivation between the period 1800-1850. In fact, as early as 1804, the Governor of the Madras Presidency wrote to his masters (the President of the Board of Commissioners) in London:

> We have paid a great deal of attention to the revenue management in this country...the general tenor of my opinion

> is, that we have rode the country too hard, and the consequence is, that it is in a state of the most lamentable poverty. Great oppression is I fear exercised too generally in the collection of the Revenues.

Of course, Dharampal also found within the same archives information about the Indian civil resistance in various regions of India in the early stages of British rule, like the one in Varanasi region around 1810-11 and in Canara around 1830, and how they were contained. But such events are not taken note of in the formal record as deliberate policy. Even petitions against grievances, though invited, would not be officially recorded unless the wording of the petition conveyed a sense of the petitioner's humility and of his (or her) limitless respect for authority.

Excerpts from one such rejected petition against the house tax imposed in Varanasi highlight this:

> ...former sooltauns never extended the rights of Government (commonly called malgoozaree) to the habitations of their subjects acquired by them by descent or transfer. It is on this account that in selling estates the habitations of the proprietors are excepted from the sales. Therefore, the operation of this tax infringes upon the rights of the whole community, which is contrary to the first principles of justice...
>
> ...It is difficult to find means of subsistence and the stamp duties, court fees, transit and town duties which have increased tenfold, afflict and affect everyone rich and poor and this tax, like salt scattered on a wound, is a cause of pain and depression to everyone both Hindoo and Mussulman; let it be taken into consideration that as a consequence of these imposts the price of provisions has within these ten years increased sixteen fold. In such case how is it possible for us who have no means of earning a livelihood to subsist?...

By their methods of extortion and other similar means, the British were able to smash Indian rural life and society by about 1820-1830. Around the same period, the extensive Indian manufactures met a similar fate. Because of deliberate British policy, the famed Indian village communities so eloquently described by Thomas Metcalfe around 1830, and by Karl Marx in the 1850s, had mostly ceased to exist.

Similar comments could be made about the narratives on Indian science and technology. Initially they were desired for their contemporary relevance and usefulness to the advancement or correction of their British counterparts. But soon after the British began to rule and control Indian life and society, the continuity of Indian knowledge and practice seemed to them a threat. Therefore it was something to be put aside so that it crumbled or decayed. Dharampal found that such a programme of 'making extinct' was contrived in practically every sphere of human activity, including the manufactures of cotton textiles, the production of Indian steel, and even the Indian practice of inoculation against small pox as early as A.D.1800.

A similar fate awaited the extensive network of Indian schools and institutions of higher learning when they began to be surveyed in the 1820s and 1830s. Ironically, it is mainly through the British archival records that one becomes aware of the extensive nature of the education network, as well as its speedy decay in the Madras and Bengal Presidency, and somewhat later in the Presidencies of Bombay and in the Punjab. Of course, the view which we get from such archival material is splintered and not integrated. But the indicators in themselves are of great value. They also provide us glimpses of pre-British life and of aspects of India's society of which we had lost track from about A.D. 1850 when society was broken up and suppressed, and an imposed alien system of education made us ignore and forget the innumerable accomplishments of our people.

Dharampal is quite clear and explicit on the uses of history. He writes:

> If we investigate these records on similar aspects further, on the basis of what is available in our archaeological, inscriptional and other historical sources, and what is still retained in the memory and consciousness of our people, we ought to be able to reconstruct our social and cultural past, and hopefully to mould our state and society accordingly.
>
> Since Independence in 1947, it is this question of reconstruction of self and society on the foundation of our priorities, values, tradition and culture that seems to have completely eluded us, particularly our scholars, administrators and politicians. We appear to have forgotten that we can look back and learn from our own past, and

> based on that experience, construct our own unique identity within the context of our own affairs as well as that of the rest of the world. What do we as a nation—without leaning on others' ideological and material crutches—want? Do we have ingenuity or not? Can we make our own points —as against aligning with one sort or another? Do we have a point to make as Indians?

When Dharampal started on this monumental work around 1965-66, he had felt then that whatever these British accounts might tell us, and howsoever incompletely, they would help us if we followed them up with further detailed and intensive explorations of such material as exists in India. Further, with the association of our own people in the exploration—in most things, still linked with their past and with much more vivid memories of it—we should, within a generation or so, begin to reconstruct our earlier life and society, linking this with our present circumstances and needs. It is distressing to note, though, that we are yet to undertake this task. Dharampal writes further:

> Today, we feel encircled by hostility—much of it in fact generated by our own ineptitude and actions. From around 1947, we have treated ourselves as cousins of the West. Dominated by the West, it may be necessary at the moment to rely on Western knowledge and products. But this can only be a short term proposal. Very soon, whatever Western know-how or products seem essential to us, we must learn to produce them in our own way, with our own material, variations and modifications.
>
> In the meanwhile, however, we must set our ordinary people free; remove the obstacles in their path relating to use of their local physical and material resources, and encourage them to use their talents to rebuild their own shattered worlds in their own various ways (even, if required, by withdrawing those laws and rules which tend to block whatever they attempt, and keeping our advice and criticism to ourselves). Only then can other local relationships and linkages begin to come alive; societal manners and memory pertaining to specific activities begin to get awakened; and the rebuilding not remain a mere copy of the past. By taking account of the world around it, Indian society will begin to integrate such elements of Western or other technologies that seem to it as relevant and stimulating for its own base.

> For all this to happen, a profound alteration in our attitudes towards our people and our past has to take place. We must enable our people to feel more self-assured, confident, hopeful, proud of their talents and capacities, and encourage them to regain their individual and societal dignity.
>
> To achieve this state, they need to acquire a better awareness—especially as children and youth—of the human past of their localities, and to establish friendly relations with other beings including all kinds of animal life and plants, rivers, lakes, ponds, hills, forests, soil, etc. which coexist with man. Similarly, we should begin to be aware of the linkage of each and every locality with the immediate region, of the region with the country, and of our country with other countries on this earth, and the earth's linkage with the cosmos.
>
> These efforts would require new texts of well told stories of localities, regions, countries, the world, and the various ideas about the beginning or non-beginning of the universe. Such knowledge and awareness would make our people feel confident and well informed and also enable them to partake of the Indian understanding of life and of natural phenomena.
>
> It would also ground them in the elements of various sciences and technologies in agriculture, animal husbandry, forestry and crafts, as well as in history, philosophy, grammar and language. Thus, by about the age of fourteen, our children—boys as well as girls—would have become competent citizens of their respective areas.

All histories are elaborate efforts at myth-making. Therefore, when we submit to histories about us written by others, we submit to their myths about us as well. Myth-making, like naming, is a token of having power. Submitting to others' myths about us is a sign that we are without power. After the historical work of Dharampal, the scope for myth-making about the past of Indian society is now considerably reduced.

If we must continue to live by myths, however, it is far better we choose to live by those of our own making rather than by those invented by others for their own purposes, whether English or Japanese. That much at least we owe ourselves as an independent society and nation.

INDIAN SCIENCE AND TECHNOLOGY
IN THE
EIGHTEENTH CENTURY

To the present day descendants of the
teachers and practitioners of Indian
sciences and technologies

...and for David, Gita and Roswitha

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List of illustrations:

Figures I–III on pages 42, 45 & 46 respectively relate to Chapter I

Diagram I on page 176 relates to Chapter XI

Figures I & II on pages 206 and 207 respectively relate to Chapter XIII

Diagrams I–VII on pages 222, 223, 225, 227, 229, 230 & 232 respectively relate to Chapter XV

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The documents reproduced in Chapters I to XVII are printed in this volume with their original spellings, punctuation and English. While all possible care has been taken in their reproduction, some errors remain in the printed text and these are because the words are illegible in the original. These errors do not make any substantive alteration in the meaning of the concerned passages.

June 1971 Dharampal

Introduction

The present volume is part of an attempt to understand the functioning of the Indian state and society some eight to ten generations back, i.e., around the period 1750, when India began to fall under European domination—firstly in the Tamil and Telugu areas, and afterwards in Bengal and elsewhere. This attempt consisted in a perusal, during 1966-70, of some of the vast Indian archival material in the English language lodged in the archives of Britain. This volume presents some of the major eighteenth and early nineteenth century documents found during this search on the subject of science and technology.

The authors of these documents came to India in various capacities: as military, medical and civilian servants of the European governments; as travellers, sometimes coming on their own, but more often sent by wealthy patrons or the newly established learned societies (like the Royal Societies of Paris and London; the Society of Arts in London, etc.); and some, like the Jesuits, came on behalf of the various Christian religious orders. According to the European scholarly canons of the time, all these were experts in their respective fields and were considered to be competent to report on what they observed or studied. Most of those, included here, spent a substantial part of their active lives in different parts of India.

Practically all European scientific and technological accounts relating to the sciences and technologies of non-European countries (including the ones reproduced here) are an outcome of the seventeenth and eighteenth century European quest for useful knowledge in these fields. The nature of the quest itself got wider and more complex with the passing of practically each decade. Few things, except finished consumer goods or gold and diamonds, etc., were noticed in the non-European world by the earlier European travellers, servants of European states, and the scientists and technologists, etc. This was partly due to the short durations which most of them spent in any particular area. But the preponderant cause was the lack of requisite comprehension amongst the learned of Europe of the prevailing non-European practices and technologies. Such lack of understanding was even more evident amongst the learned of Britain who, till about 1800, seem to have lagged behind some of the other parts of Europe in many scientific and technological fields by about fifty years.

Two examples of such lack of comprehension pertain to the practice of inoculation against smallpox, and the use of the drill plough. Till 1720, when the wife of the then British Ambassador in Turkey, having got her children successfully inoculated,[1] began to advocate its introduction into Britain, the practice of inoculation was unknown to the British medical and scientific world. Proving relatively successful, though for a considerable period vehemently opposed[2] by large sections of the medical profession and the theologians of Oxford, etc., an awareness grew about its value and various medical men engaged themselves in enquiries concerning it in different lands. The two accounts of inoculation reproduced here are a result of this post-1720 quest.

Similarly about the drill plough. The drill plough is said to have been first used in Europe by one Joseph Locatelli of Carinthia (Austria) in 1662.[3] Its first introduction in England dates to 1730. But it took perhaps another 50 years before it was used on any scale. It was used in India (according to the authors of Chapters XII and XIII) from time immemorial. Observations of its use, by the British, however could only begin in the last decades of the eighteenth century, after its awareness had dawned on the more observant amongst them.

Initially, the quest is limited and the queries which are put by the various European learned societies and individual patrons to those of their kind who have stayed or wandered in the non-European world, are fairly simple. In course of time, as knowledge gets added to knowledge and newer formulations develop in Europe, the quest becomes wider and more sophisticated and the queries begin to be concerned with the more complex. The interest in the Indian manufacture of ice; in the making of the 'Madras mortar'; in the processes of Indian iron and steel manufacture; or the observatory at Varanasi (Benares) (treated as one of the five 'celebrated observatories' of the world by the

Encyclopaedia Britannica in its editions till 1823); the search for newer chemicals and dyes, or for materials for the water-proofing of the bottom of ships (considerable quantities of which were sent with information as late as the 1790s by a Bombay correspondent to the President of the British Royal Society: Chapter XVII), arose out of rapidly multiplying but specific European needs.

It is in this context of widening horizons as well as the urgent need for materials and processes (partly resulting from constant warfare in which the Europeans were engaged during the greater part of the eighteenth century) that accounts of the kind presented here were written and submitted by individual Europeans to their respective patrons. It is in these European writings of the period (i.e., from about 1720 to 1820), that one discovers the observed details about science and technology as well as about the societies, institutions, customs and laws of various parts of the non-European world. Before this period, the European ability to comprehend this new world was limited; after about 1820, the knowledge and institutions of the non-European world also began to have much less usefulness to the problems of Europe. Further, by the 1820s, most parts of the non-European world are no longer themselves. Their institutions, sciences and technologies are not what they were 50 or a 100 years earlier, and have met the same fate as their political systems and sovereignty. By the 1820s or so, most of the non-European world had become, at least in European theory and most conventional history texts, if not actually in practice, ‘backward and barbarian’.

But the imagery of backwardness and barbarism which still serves as a descriptive label for most of the non-European world was no sudden product of the 1820s or any other decade. It grew over a fairly long period, but at a much accelerated pace after about 1780. Many of the post-1780 accounts reflect the growth of this attitude amply.

The widespread prevalence (no less amongst the learned and scholarly) of European ethnocentric bias is dramatically demonstrated by the post-1780 writings on Indian astronomy and the observatory at Benares. It comes through even in the very learned review (p.48-93) which Prof John Playfair, professor of mathematics in the University of Edinburgh, an academician of distinction, did of the then accumulated European knowledge on Indian astronomy. After a detailed examination, he arrives at the conclusion that the Indian astronomical observations pertaining to the period 3,102 years before Christ appeared to be correct by every conceivable test. Such correctness of observation was possible either through complex astronomical calculations by the Indians or by direct observation in the year 3102 B.C. He chooses the latter explanation. The reason for the rejection of the explanation that these could have been arrived at by the Indians through astronomical calculation would have implied that 'there had arisen a Newton among the Brahmins, to discover that universal principle which connects, not only the most distant regions of space, but the most remote periods of duration, and a De La Grange, to trace, through the immensity of both its most subtle and complicated operations.'[4] It became intellectually easier for him to concede this astronomy's antiquity rather than its sophistication and the scientific capacities of its underlying theories.

But even the conceding of its mere antiquity was of very short duration. With the strengthening of the fundamentalist and evangelical Christian tendencies, this concession began to look like blasphemy. Keeping in view the European historical premises, originating in the Old Testament, it was just not conceivable for anything except the stated items to have survived 'the Deluge' which was computed to have taken place in the year 2348 B.C. By 1814, though things Indian were still being half-heartedly defended by a journal like the *Edinburgh Review*, even the mere antiquity of Indian astronomy had received a final European dismissal.

While reviewing Cuvier's 'The Theory of the Earth'[5], (in which Cuvier had ridiculed and dismissed the ancient date of the Indian tables), the *Edinburgh Review* took cognisance of the changed attitudes and relationships between Europe and the non-European world, and observed: 'But though the tide of opinion seems, for some time past, to have set strongly against the high antiquity of the sciences of the East, it does not appear that the main arguments of the Historian of astronomy [i.e., Bailly] have ever been refuted.' It tried to resolve the contradiction between the Mosaic and Christian belief, and the earlier date of the Indian tables, by advancing the proposition, that 'the early date of that Astronomy, and the usual date of the Deluge, may be perfectly reconciled, on the supposition that the former is a fragment of antediluvian science, which had escaped the general destruction.' Such a solution of the controversy was, however, no longer practicable, nor necessary from the viewpoint of European scholarship, in what had by then become an exclusively European century.

Even when the ancientness of Indian astronomy was being conceded, as was done by Prof Playfair, it was difficult to admit that the eighteenth century Indian astronomers and scholars on the subject had any real competence. According to Playfair, the eighteenth century Indian astronomer had 'little knowledge of the principles on which his rules are founded, and no anxiety to be better informed.'[6] Yet it was only through intercourse with Indian astronomers and by means of instruction and data received from them that the European knowledge of Indian astronomy could be acquired. It was thus acquired by M. Le Gentil during his visit to India about 1769. According to the *Encyclopaedia Britannica*: 'During the time of his stay in Hindustan, the Brahmins had been much more familiar with him on account of his astronomical knowledge, than they usually were with Europeans, and he thus had an opportunity of obtaining considerable insight into their methods of calculation. In consequence of this instruction he published tables and rules, according to the Indian method, in the Academy of Science for 1772.'[7]

The general incommunicativeness of eighteenth century Indian scholars and specialists in the various fields had two probable roots: one, the usual secretiveness of such persons, and, two, the very sophistication and complexity of their theories which in their view (whether rightly or wrongly) would not have been understood by most Europeans. It is possible that the various sciences and technologies were on a decline in India around 1750 and, perhaps, had been on a similar course for several centuries previously. But there seems little doubt that the processes, methods, theories and formulations described in the contemporary accounts included in this volume were very much a living reality in the areas of India to which they pertain. Whether these were also used or taught or discussed in most other parts is a matter for detailed investigation, not only into the English language records, but more so in the surviving indigenous Indian records of the period, and also the Indian archival material in other foreign languages. How do mid-eighteenth century Indian sciences and technologies compare with the sciences and technologies in earlier periods requires similar investigation.

The later eighteenth century European ethnocentric preoccupations had other dimensions also. Some of these are expressed in Chapters III and V, whereby everything existing elsewhere is visualised to have had its origin in India. A different dimension was expressed in propositions like: 'The Hindu religion had its origin in the British Isles,'[8] (which was held to be the *Sweta Dwipa* of the Hindu classics). Though perhaps not so intended, all of these conflicting speculations and formulations ultimately led to the subversion of the non-European world. Many directly confirmed the growing European view of the barbarism and ignorance of the non-Europeans; the others served the same purpose by becoming easy targets for European ridicule and contempt.

II

Four of the accounts included in this volume deal with astronomy and two with mathematics. The observatory at Benares described by Sir Robert Barker, after a visit to it in 1772, still exists more or less intact and is at present known as the Man Mandir. It stands only a few hundred yards away from the Dasasvamedha Ghat. Its appearance today seems even more neglected (It is tragic that one of the five celebrated observatories of the world (and in India the most celebrated), though still intact, remains in complete neglect. Its counterparts in Britain, France, etc. are greatly cherished and serve as the repositories and centres of their respective astronomical knowledge. India owes that much to itself and its people that places like the Man Mandir are duly cherished and looked after.) than that described two centuries ago, except that a few plates have been fixed indicating the names of the various *yantras* (instruments) in Hindi and English. Two other plaques indicate the period of the building and the date of the erection of the observatory. While the building is stated to have been built in the late sixteenth century, the relevant plaque states the erection of the observatory in the early eighteenth.

Such playing about with the dates of the founding of the observatory has a curious tale to tell. Barker's account was published in the *Transactions* of the British Royal Society in 1777 and it put the erection of the observatory some two centuries previously. In 1792, in conformity with the request of a Fellow of the Royal Society, another report on the observatory was received from one J.L. Williams of Benares. This was published in the *Transactions* in 1793.[9]

One of the two main points which this later account, as if in passing, tried to make was that the observatory only came into being some 50-60 years earlier and was not built in the sixteenth century—as stated by the Bengal commander-in-chief in his article published in 1777. To support this contention, it produced what it claimed to be the opinion of the Indian magistrate of Benares (who, incidentally, with his colleagues was in the process of being displaced by British judges and magistrates through the newly enacted 'Cornwallis' Judicial Regulations). The magistrate is alleged to have said that though the building was built by 'Rajah Maunsing, for the repose of holy men and pilgrims', the 'observatory was built, by the Rajah Jeysing.' Further, it was begun in 1794 *sumbut* (A.D. 1737) and finished in two years and that the Rajah died in 1800 *sumbut* (A.D. 1743). To this was added the even 'weightier' opinion of the Brahmins of Benares 'one of whom is professor of astronomy in the new founded college.' According to him, 'they all agreed that this observatory never was used, nor did they think it capable of being used, for any nice observations; and believe it was built more for ostentation, than the promotion of useful knowledge.' Besides these two points, the article gave the measurements of the various instruments but stated that 'from the want of sufficient knowledge of the science of astronomy, I have not been able to describe the different instruments, and their uses, satisfactorily; however, you may rely on the measurements being taken with the greatest exactness.'

The subject of the Benares observatory was again taken up in 1798 by William Hunter, an assistant to the British Resident at the Marhatta capital at Poona, in an article, 'Some account of the astronomical labours of Jayasinha, Raja of Ambhere, or Jayanagar'. The interest in Raja Jayasinha is explained: 'Arising superior to the prejudices of education, of national pride and religion', Jayasinha strove to enrich his country 'with scientific truth derived from a foreign source', in this particular instance, Europe. The writer was quite candid and outspoken about his purpose. He said: 'I have always thought, that after having convinced the eastern nations of our superiority in policy and in arms, nothing can contribute more to the extension of our national glory, than the diffusion among them of a taste for European science. And as the means of promoting so desirable an end, those among the natives who have penetration to see, and ingenuousness to own its superior accuracy and evidence, ought to be cherished.'[10]

This article made an attempt to provide documentary evidence of the Benares observatory as having been the creation of this early eighteenth century Raja Jayasinha by quoting from what is called the *Zeej Mohammedshahy*. (If it still exists, much more needs to be known about this mid-eighteenth century document: how it came to be written, by whom, under whose patronage and in what year.) According to this document, having 'assembled the astronomers and geometricians of the faith of Islam and the Brahmins and Pundits, and the astronomers of Europe' etc., Jayasinha 'bound the girdle of resolution about the loins of his soul, and constructed (at Dehly) several of the instruments of an observatory.' And 'in order to confirm the truth of these observations' i.e., at Dehly, 'he constructed instruments of the same kind in Sewai Jeypoor and Matra, and Benares and Oujein.' With the foregoing statement from the *Zeej Mohammedshahy*, the documentary proof ended. For the rest, he added: 'The observatory at Benares having been described by Sir Robert Barker and Mr Williams, I have only a few remarks to offer, in addition to the account delivered by those gentlemen' [11] and the writer made some more observations on its measurements, etc.

Various other Britishers seem to have gone and made reports on the Benares observatory in the early decades of the nineteenth century. But the subject soon disappeared from public discussion. It was re-opened in 1920 by the author of 'A Guide to the Old Observatories',[12] originally published by the Archaeological Survey of India. It stated that the Man Mandir i.e., the actual building of the Benares observatory, 'was built about the beginning of the seventeenth century. The astronomical instruments were added by Jai Singh about A.D. 1737.' It said further: 'The date is not certain, and nearly every writer gives a different one.'

It further observed, ‘Prinsep wrote: “The building was converted into an observatory by Jaysingh in A.D. 1680” and refers to a supposed description of it by Tavernier.’ Dismissing all these other dates (Prinsep, with a footnote: ‘Tavernier died in 1689, three years after Jai Singh’s birth.’) this author concluded that ‘Williams’ date for the observatory at Benares, 1737, may be accepted’ as he ‘on all points that can be verified, is extremely reliable’, and quoted Hunter as speaking ‘of the accuracy of Mr Williams’ measurements.’[13]

The eighteenth century dating of the Benares observatory thus rests on the two articles published in 1793 and 1798 respectively; the first, at the instance of a Fellow of the Royal Society, and the second, in a longer piece wishing to convince the Eastern nations of the superiority of European eighteenth century science with a view to ‘contribute more to the extension of our national glory.’ What Tavernier said in his published, ‘Travels’ was: ‘Near to this great Pagod, upon the summer-west, stands a kind of a college which the Raja Jesseing the most potent of all the idolaters in the Mogul’s empire, built for the education of the youth of the better sort.’[14] Tavernier visited Benares in 1655-6. It may be added that quite a few ‘Jayasinha’ (spelt variously) have been Rajas of ‘Ambhere’ through the centuries. It is possible that this fact has also contributed to different writers claiming widely separate dates for the construction of the Benares observatory.

A rather curious point arises here out of this chronology about the dating of the Benares observatory: Barker along with Pearse, and A. Campbell visited the observatory in 1772. If the observatory was actually built in 1737, it was only 35 years old at this date. Both Barker and Pearse specifically state that it had been there for some two centuries. They must have arrived at this statement after meeting and conversing with persons who, if the observatory had been constructed only 35 years previously, must have been eye witnesses to its construction. As there was no controversy in 1772 about the date of the construction of the observatory, it is inconceivable that Barker’s informants misled him on this point. The conversion of two centuries into 35 years is the most fabulous aspect of this later controversy.

Next is the long and learned review (Chapter II), 'Remarks on the Astronomy of the Brahmins', by John Playfair, read by him in 1789. In this article, the author begins by referring to certain astronomical tables received from the East Indies by European scholars at an early stage in their contact with the East. Some of these tables were received from Siam and their 'epoch' corresponded to 21 March 638 A.D. But the point to note was that the 'meridian' of these tables was not Siam but Benares!

Other tables received from South India had one thing in common. Their 'epoch' coincides with the era of *Kaliyuga*, that is, with the beginning of the year 3102 B.C. Prof Playfair begins by enquiring whether the 'epoch' was real or fictitious; that is, whether the planetary positions at that time were actually observed or were merely calculated back from the 'epochs' of more modern tables to coincide with a mythical *Kaliyuga*.

Prof Playfair observes that it is not for astronomy, even in its most perfect state, to go back 46 centuries and to ascertain the situation of the heavenly bodies at so remote a period, except with the help of lately developed Integral Calculus and the Theory of Gravitation. He finds that the positions of the planets as given in these tables is very close to the position as calculated back with the help of modern Integral Calculus and the Theory of Gravitation. All other systems of calculation, whether Chaldean or Egyptian or Greek which the Hindus might have used for their purpose gave very different results.

So for him, the inescapable conclusion is that these positions were observed by the Brahmins, and it is rather a wonder that the Brahmins could do so rather precisely at so distant a past. Prof Playfair also observed that the construction of these tables implied a good knowledge of geometry and arithmetic, as well as the possession of a Calculus equal to Trigonometry.

The paper (Chapter IV) by Colonel T.D. Pearse, sent by him to the Royal Society, London, and surviving in their archives, refers to the Indian knowledge of the four Satellites of Jupiter and the seven Satellites of Saturn. Pearse further felt that the Indians must have possessed some kind of telescopic instruments to have acquired such detailed knowledge. The author of Pearse's memoirs, while including a slightly modified version of this piece in the memoirs, states:

> We cannot pass this interesting communication without offering some reflection upon the subjects it embraces. The circumstances of the four girls dancing round the figure of

> Jupiter, as they ought to be according to the Brahmin's statement to Colonel Pearse, is a strong argument in favour of the superior knowledge of the heavenly bodies which the ancient Arabians and Hindus possessed. The four dancing girls evidently represent the four satellites of Jupiter. These circumjovial satellites (as they are styled by modern astronomers from the quirk of their motions in their orbits) were not known in Europe before the year 1609, and the third and fourth only are visible, and this but rarely and in the clearest atmosphere to the naked eye. But it is truly interesting and curious that the figure of Saturn should be represented with seven arms. At the time Colonel Pearse wrote his letter to the Royal Society, the sixth satellite of Saturn had not been discovered: it was first discovered by Herschel on the 28 August 1789; and the seventh satellite, which the seventh arm of the figure, without dispute, must be intended to represent, was not discovered by Herschel until he had completed his grand telescope of 40 feet focal length, when it was first observed by him on the 17 September 1789. All the satellites of Saturn are so small, and the planet is so remote from the earth, that the best telescopes are necessary for observing them. May not the seventh arm *having hold of the ring* denote a circumstance connected with the orbits of these planets, which is that the planes of their orbits so nearly accord with that of the ring, that the difference is not perceptible? Undoubtedly, the ancient astronomers must have possessed the best instruments: probably differing from modern ones, but fully as powerful.

The writer added further: 'We are not aware that the Royal Society in any of its printed papers have noticed Colonel Pearse's communication, but our imagination, warmly interested as it has been in all that relates to the subject of the present memoir, has pictured the probability that Colonel Pearse's paper may have met the eye of Herschel, and may have been an additional spur to the indefatigable and wonderful labours of that great man.'[15]

Reuben Burrow's unpublished paper (Chapter III) was addressed to the British Governor General Warren Hastings soon after Burrow had come to India to take up his new job at Calcutta. It is highly speculative and in a way is more in line with the contemporary intellectual tradition of the European enlightenment of the eighteenth century. (The tradition has, in fact, continued well into the present time; only as time passed, however, it has become more and more Eurocentric. The late 19th century dictum, ‘Except the blind forces of nature, nothing moves in this world which is not Greek in its origin,’ enunciated by Maine (one-time Law Member of the Governor General’s Council in India) was merely an intellectual and scholarly expression of the mounting Eurocentric character of this speculativeness.) Though in itself it does not provide much factual data, and perhaps comes to even several erroneous conclusions as we would see them today, its very speculativeness seems to have provided inspiration and stimulus to a number of subsequent enquiries about Indian sciences, particularly mathematics. The article ‘A Proof that the Hindus had the Binomial Theorem’ by Burrow himself, and the later dissertation by H.T. Colebrooke on ‘Hindu Algebra’ (given as introduction to his translation of ‘Algebra with Arithmetic and Mensuration’ of Brahmagupta and Bhascara) decidedly follow such speculativeness. Acknowledging Burrow’s contribution, particularly in bringing Indian Algebra to the notice of Europeans, the article on ‘Algebra’ in the *Encyclopaedia Britannica* (8th edition) stated:

> We are indebted, we believe, to Mr Reuben Burrow for some of the earliest notices which reached Europe on this very curious subject. His eagerness to illustrate the history of the mathematical sciences led him to collect oriental manuscripts, some of which in the Persian language, with partial translations, were bequeathed to his friend Mr Dalby of the Royal Military College, who communicated them to such as took an interest in the subject, about the year 1800.[16]

The article (Chapter V) on ‘the Binomial Theorem’ was published in 1790 in Calcutta. Till then, and in British reference books like the *Encyclopaedia Britannica* well into the twentieth century, the discovery of this theorem has been credited to Newton.[17] Some thirty years later, Burrow’s article was followed by another titled ‘Essay on the Binomial Theorem; as known to the Arabs’.[18] This later article was a sequel to the first by R. Burrow, and it concluded: ‘It plainly appears, that whatever may have been the case in Europe, yet long before the time of Briggs the Arabians were acquainted with’ the Binomial Theorem.

(Briggs was teaching around 1600, about a century before Newton).

This later author quoted Dr Hutton concerning the origin of the Binomial Theorem in Europe. The following, from the longer extract of Hutton's account, is worth quoting:

> Lucas De Burgo extracted the cube root by the same coefficients, about the year 1470...Briggs was the first who taught the rule for generating the coefficients of the terms, successively one from another, of any powers of a binomial, independent of those of any other power...This theorem then being thus plainly taught by Briggs about the year 1600, it is surprising how a man of such general reading as Dr Wallis was, could be ignorant of it...and fully ascribe the invention to Newton...But I do not wonder that Briggs remark was unknown to Newton, who owed almost everything to genius and deep meditation, but very little to reading: and I have no doubt that he made the discovery himself, without any light from Briggs.[19]

H.T. Colebrooke's dissertation on 'Hindu Algebra', resulting from all the preceding investigations by men like R. Burrow, F. Wilford, S. Davis, Edward Strachey, John Taylor, etc., and from his own considerable knowledge, is a learned survey and comparison of the developments in Europe and India. But the conclusion that Indian Algebra, etc., may have had an independent development proves difficult for him to digest. Reversing the speculations of Burrow, he comes to the conclusion that the 'Algebra of the Greeks', imperfect though he admits it to be, 'was made known to the Hindus by their Grecian instructors in improved astronomy.' (The reviewer of 'Algebra, with Arithmetic and Mensuration', in *The Edinburgh Review* (November 1817) however thought differently and stated that it 'could not have been derived from Greece.' Commenting on Colebrooke's opinion he added: 'Mr Colebrooke, after demonstrating the excellence of this algebra, and comparing its more perfect algorithm and its superior advancement with the Greek algebra, as explained in the work of Diophantus, seems nevertheless willing to admit, that some communication about the time of the last mentioned author, may have come from Greece to India, on the subject of the Algebraic Analysis. Of this we are inclined to doubt; for this simple reason, that the Greeks had nothing to give on that subject which it was worth the while of the Indians to receive. Mr Colebrooke seems inclined to this concession, by the strength of a philological argument, of the force of which we are perhaps not sufficiently sensible. It seems however certain, that the facts in the history of Algebraic Analysis, taken by themselves, give no countenance to the supposition.') But wishing to be gracious and charitable, he infers that 'by the ingenuity of the Hindu scholars, the hint was rendered fruitful and the algebraic method was soon ripened from that slender beginning to the advanced state of a well arranged science.'[20]

III

As contrasted with the eighteenth century European consideration and discussion on Indian sciences, the accounts of Indian technology did not give rise to passionate controversy. Perhaps such passion was neither possible nor necessary, as it ordinarily did not challenge any fundamental European dogma or belief. The results of the technology were there for all to observe and utilise. And it may incidentally be the lack of such controversy itself that explains the complete current ignorance of most aspects of this technology.

It appears that Indian medical men (with whatever names they may be termed at the end of the eighteenth century) made considerable use of surgical techniques in different parts of India. According to Colonel Kyd in 'Chirurgery (in which they are considered by us the least advanced) they often succeed, in removing ulcers and cutaneous irruptions of the worst kind, which have baffled the skill of our surgeons, by the process of inducing inflammation and by means directly opposite to ours, and which they have probably long been in possession of.'[21] Dr H. Scott (Chapter XVII) seems to corroborate the above and further reports the prevalence of plastic surgery in Western India, in his letters to the President of the Royal Society, London. In 1972, he states:

> In medicine I shall not be able to praise their science very much. It is one of those arts which is too delicate in its nature to bear war and oppression and the revolutions of governments. The effects of surgical operation are more obvious, more easily acquired and lost by no means so readily. Here I should have much to praise. They practice with great success the operation of depressing the crystalline lens when become opaque and from time immemorial they have

> cut for the stone at the same place which they now do in Europe. These are curious facts and I believe unknown before to us.[22]

Two years later he refers to the 'putting on noses on those who lost them' and sends to London a quantity of 'Caute', the cement used for 'uniting animal parts'.[23]

Inoculation against the smallpox seems to have been universal, if not throughout, in large parts of Northern and Southern India, till it was banned in Calcutta and other places under the Bengal Presidency (and perhaps elsewhere) from around 1802-3. Its banning, undoubtedly, was done in the name of 'humanity', and justified by the Superintendent General of Vaccine (A vaccine (the Latin *vacca*, meaning cow) from the cow, for use in the inoculation against smallpox was manufactured by Dr E. Jenner in 1798. From then on, this vaccine replaced the previous 'variolous' matter, taken from human agents. Hence the method using the 'vaccine' came to be called 'Vaccine Inoculation'.) Inoculation in his first report in March 1804.[24]

The most detailed account of the practice of inoculation against the smallpox in India is by J.Z. Holwell, written by him for the College of Physicians in London.

After giving the details of the indigenous practice, Holwell stated (Chapter VIII, pg 158): 'When the before recited treatment of the inoculated is strictly followed, it is next to a miracle to hear, that one in a million fails of receiving the infection, or of one that miscarries under it.' It is possible that Holwell's information was not as accurate as of the newly appointed Superintendent General of Vaccine Inoculation in 1804. According to the latter, fatalities amongst the inoculated were around one in two hundred amongst the Indian population and amongst the Europeans in Calcutta, etc., 'one in sixty or seventy'.[25] The wider risk, however, seems to have been in the spreading of disease by contagion from the inoculated themselves to those who for one reason or another had not been thus inoculated.

It is possible that there were some areas in India where inoculation did not prevail. This, of course, is a matter for enquiry. But wherever it did, it appears to have been universal over a whole tract. After the imposition of British rule in Bengal, Bihar, Orissa, areas of Madras Presidency, etc., this situation seems to alter. According to the Superintendent General of Vaccine Inoculation, a section of the people, either 'from indigence' or 'from principle', did not any longer (*circa* 1800) receive the inoculation.[26] Those who did not receive it 'from principle' seem to have been the Europeans in Calcutta, etc. Partly this may have been due to the greater mortality (i.e. one in sixty or seventy, as indicated above) amongst them. Further it may have also resulted from the persistence of Christian theological objections to any inoculation amongst them.[27]

Not receiving it 'from indigence', on the other hand, pertained to sections of the Indian population. Like many other categories of specialists, (including school teachers, doctors, establishments of religious institutions and places, village establishments, etc.), it is probable that the inoculators in India had also been maintained on subventions from public revenues. With the imposition of British rule, the Indian fiscal system began to collapse and various categories of specialists and functionaries were thrown out on the streets and left to wholly fend for themselves. It is this development, and the simultaneous deepening of poverty amongst the people, that most probably resulted in many not being inoculated 'from indigence'. Such a situation must have naturally made the practice of inoculation seem even more undesirable to the Europeans who, while they themselves did not like to be inoculated, yet could not function without whole contingents of Indian domestic servants.

So what, till the latter part of the eighteenth century, when practised universally in any tract, was a relatively effective method involving no contagious effects (since all were similarly inoculated), had begun to seem by 1800 a great hazard to the Europeans in Calcutta. But in spite of the bannings, prohibitions, etc. resorted to in Calcutta and other cities and towns, the introduction of vaccine inoculation was very halting. Such halting development must have been caused by insufficient provision of resources or by sheer indifference. Or, as hinted by the officiating Superintendent General of Vaccination for N.W.P. (the present U.P.) in 1870, it may also have been caused by the peoples' reluctance to get vaccinated as, according to this authority, the indigenous inoculation possessed 'more protective power than is possessed by vaccination performed in a damp climate.'[28] Whatever the causes, the indigenous inoculation seems to have been still practised around 1870. For areas near Calcutta, those who were not so inoculated are estimated at 10 per cent of the population around 1870, and for the Benares area at 36 per cent.[29] The frequent smallpox epidemics which were rampant in various parts of India in the nineteenth and early twentieth century may largely be traced back, on the one hand, to the state's backwardness and indifference in making the requisite arrangement for universal vaccination; and on the other hand, to having made the existence of the indigenous practice of inoculation most difficult not only by withdrawing all support for it, but also forcing it to be practised secretly and stealthily.

Another important point which emerges from Mr Holwell's account of the Indian method of inoculation relates to the prevalence of some theory of bacterial infection amongst the mid-eighteenth century Indian inoculators. According to them: 'The small-pox is more or less epidemical, more mild or malignant, in proportion as the air is charged with these animalculae', i.e. bacteria, and that these 'adhere more closely, and in greater numbers, to glutinous, fat, and oily substances.' That these '*imperceptible animalculae* floating in the atmosphere...are the cause of all epidemical diseases, but more particularly of the small-pox;' that 'they pass and repass in and out of the bodies of all animals in the act of respiration, without injury to themselves, or the bodies they pass through;' but 'such is not the case with those that are taken in with food,' as these 'are conveyed into the blood, where, in a certain time, their malignant juices excite a fermentation' and end 'in an eruption on the skin.'[30]

Similarly interesting accounts are available on Indian agriculture. The observation by Alexander Walker (Chapter XII), that 'the practice of watering and irrigation is not peculiar to the husbandry of India, but it has probably been carried there to a greater extent, and more laborious ingenuity displayed in it than in any other country,'[31] is in dramatic contrast to present day text-book accounts of 'the comparative absence of artificial irrigation' in eighteenth century India.[32] How Indian agricultural principles, implements and practices (and these may have somewhat varied in different parts of India itself) compared with those elsewhere (China, Egypt, various countries of Europe, etc.), can only be known after a detailed comparative study of the subject. The causes of relative scarcity of resources constantly facing the Indian husbandman also need to be enquired into. It is probable that in most parts of India such scarcity was of late eighteenth century origin, and directly resulted from political causes. But it seems clear that besides widespread artificial irrigation, the practices of (i) crop rotation, (ii) manuring, (iii) sowing by means of the drill plough, and (iv) use of a variety of other implements were fairly widespread. The nature and quality of soils seemed to be well understood and in areas like Malabar, certain species of paddy are propagated by cuttings. The use of the drill plough, however, (and perhaps also of some other implements and practices), as noted in Chapter XIII, varied from husbandman to husbandman, the poor not being in a position to use it as it required larger resources not only in implements but also in draught cattle. The latter-day decline in the variety and efficiency of agricultural implements seems to be a result of the general economic impoverishment brought about by the state appropriating all it possibly could in the late eighteenth and the nineteenth centuries. (The material concerning the proportion of the gross produce of agriculture taken away by the state constitutes a major portion of British Indian archival documents. Theoretically, the land revenue due to government was fixed at 50%. In large parts of India under British rule till 1855 or so, the proportion that during most years actually went towards governmental land revenue was appreciably higher. For instance, according to certain enquiries in the Madras Presidency Ryotwary areas during the 1850s, about one-third of the irrigated land had over the years altogether gone out of cultivation as the amount of land revenue on such land had begun to approximate the gross produce itself, and at times even exceeded it.)

The composition of the 'Madrass Mortar' (Chapter IX) is very curious, while the process of making paper (Chapter XI) is perhaps not very different from that currently in use in the manufacture of hand-made paper. Chapter X, on the process of making ice, however, is still more fascinating. It was first published in 1775 in London. But it appears that this subject and the manner in which ice was made had been observed even earlier by a number of Britishers in India and had given rise to considerable scientific curiosity in England. The artificial making of ice seems to have been till then unknown in Britain (and perhaps also in other European countries). The observation that 'boiling the water is esteemed a necessary preparative to this method of congelation' aroused particular interest. Sir Robert Barker, the author of this article, while referring to this point wondered 'how far this may be consonant with philosophical reasoning' (i.e., with scientific proof). As a consequence, after carrying out various experiments, the professor of Chemistry at Edinburgh University provided the following explanation:

> The boiled and common water differ from one another in this respect; that whereas the common water, when exposed in a state of tranquility to air that is a few degrees colder than the freezing point, may easily be cooled to the degree of such air, and still continue perfectly fluid, provided it still remains undisturbed: the boiled water, on the contrary, cannot be preserved fluid in these circumstances; but when cooled down to the freezing point, if we attempt to make it the least colder, a part of it is immediately changed into ice; after which, by the continued action of the cold air upon it, more ice is formed in it every moment, until the whole of it gradually congealed before it can become as cold as the air that surrounds it. From this discovery it is easy to understand, why they find it necessary to boil the water in India, in order to obtain ice.[33]

Dr H. Scott (Chapter XVII) makes mention of many other processes and dyeing and other agents and substances. 'Dammer: a substance in universal use through the whole Eastern world,'[34] for covering the bottom of ships and for other uses where water proofing was required, was one such.

But the substance which seems to have evoked most scientific and technical interest in the Britain of the 1790s was the sample of *wootz* steel sent by Dr Scott to Sir J. Banks, the President of the British Royal Society. The sample went through examination and analysis by several experts.[35] It was found in general to match the best steel then available in Britain, and according to one user, 'promises to be of importance to the manufactures' of Britain.[36] He found it 'excellently adapted for the purpose of fine cutlery, and particularly for all edge instruments used for surgical purposes.' After its being sent as a sample in 1794 and its examination and analysis in late 1794 and early 1795, it began to be much in demand; and some 18 years later the afore-quoted user of steel stated, 'I have at this time a liberal supply of *wootz*, and I intend to use it for many purposes. If a better steel is offered to me, I will gladly attend to it; but the steel of India is decidedly the best I have yet met with.'[37]

Till well into the nineteenth century, Britain produced very little of the steel it required and imported it mostly from Sweden, Russia, etc. Partly, Britain's lag in steel production was due to the inferior quality of its iron ore, and the fuel, i.e., coal, it used. (Writing in 1824, J.M. Heath, later a leading manufacturer of iron and steel at Sheffield, stated: 'It is well known that England is entirely dependent upon foreign countries for all the iron required for this purpose, and last year the importation of foreign iron into England, for the purpose of making steel alone, exceeded 12,000 tons...Year after year does the Society for the Encouragement of Arts offer a premium for the manufacture of English Iron fit for steel making, and to this time the premium has never been claimed; nor is it likely that it ever will, from the nature of the English ores, and the inferior quality of the English fuel.' (*Madras Public Proceedings*, January 1825)) Possibly such lag also resulted from Britain's backwardness in the comprehension of processes and theories on which the production of good steel depended.

Whatever may have been the understanding in the other European countries regarding the details of the processes employed in the manufacture of Indian steel, the British, at the time *wootz* was examined and analysed by them, concluded 'that it is made directly from the ore; and consequently that it has never been in the state of wrought iron.'[38] Its qualities were thus ascribed to the quality of the ore from which it came and these qualities were considered to have little to do with the techniques and processes employed by the Indian manufacturers. In fact it was felt that the various cakes of *wootz* were of uneven texture and the cause of such imperfection and defects was thought to lie in the crudeness of the techniques employed.

It was only some three decades later that this view was revised. An earlier revision in fact, even when confronted with contrary evidence as was made available by other observers of the Indian techniques and processes, was an intellectual impossibility. 'That iron could be converted into cast steel by fusing it in a close vessel in contact with carbon' was yet to be discovered, and it was only in 1825 that a British manufacturer 'took out a patent for converting iron into steel by exposing it to the action of carburetted hydrogen gas in a close vessel, at a very high temperature, by which means the process of conversion is completed in a few hours, while by the old method, it was the work of from 14 to 20 days.'[39]

According to J.M. Heath, founder of the Indian Iron and Steel Company, and later prominently connected with the development of steel making in Sheffield, the Indian process appeared to combine both of the above early nineteenth century British discoveries. He observed:

> Now it appears to me that the Indian process combines the principles of both the above described methods. On elevating the temperature of the crucible containing pure iron, and dry wood, and green leaves, an abundant evolution of carburetted hydrogen gas would take place from the vegetable matter, and as its escape would be prevented by the luting at the mouth of the crucible, it would be retained in contact with the iron, which, at a high temperature, appears [from the above-mentioned patent process] to have a much greater affinity for gaseous than for concrete carbon; this would greatly shorten the operation, and probably at a much lower temperature than were the iron in contact with charcoal powder.[40]

And he added:

> In no other way can I account for the fact that iron is converted into cast steel by the natives of India, in two hours and a half, with an application of heat, that, in this country, would be considered quite inadequate to produce such an effect; while at Sheffield it requires at least four hours to melt blistered steel in wind-furnaces of the best construction, although the crucibles in which the steel is melted, are at a white heat when the metal is put into them, and in the Indian process, the crucibles are put into the furnace quite cold.[41]

The above quoted British authority however did not imply that the Indian practice was based on a knowledge 'of the theory of his operations' by the Indian manufacturer. He felt it to be impossible 'that the process was discovered by any scientific induction, for the theory of it can only be explained by the lights of modern chemistry.'[42] And feeling that 'all speculation upon the origin of the discovery seems useless', he proceeded to deal with the more practical matters.

Several scores of British accounts (some more, some less detailed) pertaining to widely separated areas of India, and perhaps pertaining to about a hundred districts, are available on the Indian manufacture of iron and steel. Though some date to the 1790s, most were written during the period 1820-1855. That included in Chapter XV is probably the most graphic and detailed amongst them, while the one in Chapter XVI tries to provide some perspective and comparison of the different processes and corresponding details prevailing in different countries. Though there seems to be some fairly detailed accounts of the process of Indian iron and steel manufacture in other European languages dating back to the late seventeenth century,[43] that in Chapter XIV is probably one of the earliest British accounts of it.

The design, measurements, and construction of the furnaces and accessory implements, described in Chapter XV, require much detailed examination by experts. Similar examination is essential of the large amounts of data provided in Chapters

XV and XVI. But a cursory study of the data seems to indicate that the proportion of iron recovered from the ore and the amount of charcoal required to produce a given quantity of crude iron in Central India is comparable with the respective ratios pertaining to the manufacture of iron and steel in Sweden, etc. It is possible that these quantities varied considerably in different parts of India. Maybe, with the continuous deterioration which had set in, the consumption of fuel in the production of iron increased considerably. It is perhaps due to this later development, or basing himself on the data from some selected areas, that Mahadeva Govind Ranade remarked (in the 1890s) that indigenous Indian 'processes involve a great waste of power and resources, as much as fourteen tons of fuel being required to produce one ton of iron.' And thus he concluded: 'Besides the effects of foreign competitors, the collapse of the iron industry has been brought about by the increasing scarcity of fuel.'[44]

According to Chapter XV,[45] 140 seers of charcoal produced 70 seers of crude iron at Aggeriya, etc., in the district of Jabalpur. At Jowli, in the same district, 165 seers of charcoal were required to produce 77 seers of crude iron. How much charcoal was required to convert the crude into malleable and wrought iron is not indicated in Chapter XV. However, considering that the amount of charcoal required to convert the ore into crude iron is of the same order as the quantities required in European countries, it may be inferred that the requirement of fuel in subsequent processes would not have been very different.

It is not easy to estimate the total number of such furnaces which may have been in operation in various parts of India in the eighteenth century. Certain mid-nineteenth century enumerations, however, place the number of furnaces operating in certain districts, talooks, etc., in hundreds. It is, therefore, probable that the number of iron and steel furnaces functioning throughout India in the latter part of the eighteenth century was in the region of 10,000. According to the data given in Chapter XV, the production of iron per furnace amounted to somewhat above half a ton per week. Assuming that a furnace on an average worked about 35-40 weeks a year, the potential production of iron per furnace may be assumed at 20 tons annually.

Besides the furnaces and accessories so graphically described in Chapter XV, certain other devices varying from area to area also appear to have been used in Indian metallurgy. One such was the use of the *Panchakki* (water-mill) in the crushing of ore by the manufacturers of Kumaon and Garhwal. According to J.D. Herbert and J. Manson 'in reducing the ore to fragments, the Dhunpoor miners employ the *Panchakki* or water-mill. When water is present no better plan can be devised.'[46]

Several questions arise out of the material on technology described and discussed here. One of them arises from the generally shared European opinion—at times asserted—that the Indian manufacturer of iron and steel (and, in other instances, of other commodities, or practitioners in other professions) could not have had any knowledge 'of the theory of his operations'. Though such opinions essentially originated from the ethnocentric views and inclinations (Even the British Royal Society does not seem to have remained untouched from such inclinations. Referring to the letter of Dr Scott on *wootz,* it quoted him as having written that it 'admits of a harder temper than anything known in that part of India.' What Dr Scott had actually stated was that 'it appears to admit of a harder temper than anything we are acquainted with.' As is obvious, Dr Scott's 'we' implied 'we in Europe'. But as this must have seemed inadmissible in the pages of the *Philosophical Transactions*, the observation got altered to 'than anything known in that part of India.' (See *Philosophical Transactions*, vol.85, p.322; and chapter XVII, pp.256 in this volume).) of the societies to which such observers belonged, and were not in their essence derived from the subject observed and described, these, as mere statements which generally hold true at all times, need not be disputed. But most practitioners of a profession which they have learnt after a long apprenticeship and in which their essential job is to repeat ever more perfectly what they had done before, never require, and seldom possess, such knowledge. The possession of such knowledge and its development and refinement is, at all times, the function of a separate, though interlinked, group. Such division between the practitioners and the theoreticians is currently more evident than ever before.

It is possible that the link between the practitioners of the various techniques or professions and the professors of the theoretical knowledge relating to them had largely snapped in India by the end of the eighteenth century. It is even probable that though not altogether snapped, such a break had begun to take place centuries earlier. This, however, is a view which cannot be determined by mere conjecture. Its substantiation requires detailed studies of Indian techniques and processes as they operated over several centuries up until the early nineteenth.

Even if these links had already snapped but the practices had continued, it is very probable that in a changed political climate—resulting, for instance, from the success of the early eighteenth century resurgence—they could have been restored by fresh interaction between the practitioners and the surviving professors with their knowledge of the theoretical aspects. Or even forged anew.

Another question that arises from the above discussion on the manufacture of Indian iron and steel is that if the manufacturing processes were so very superior and widespread throughout the country, why did they disappear? So far, our knowledge of such widespread manufacture has itself been very scanty. Therefore, answers to such a question at present can merely be tentative. The disappearance seems to have resulted mainly from large-scale economic breakdown resulting from hostile state policy. From about 1800 onwards, India was to be treated as a consumer of British manufactures. Yet some of the British in India did visualise the undertaking of large scale production of iron and steel in India. But even they, when they came forth with such plans, were at great pains in stating that such production would in no way injure the production in Britain or the consumption of British iron in India. Even this type of proposition was, however, difficult for the British Government to contemplate. For example, replying to an early application for setting up such works in the Bengal area, the London authorities in 1814 stated: 'But as we entertain strong doubts as to the policy of encouraging the prosecution of such works to any extent, we direct that no further expense may be incurred.'[47]

IV

Many other aspects of science and technology are not at all referred to in the accounts which are reproduced in the following pages. Textiles, armaments, horticultural techniques, or the breeding of animals are among those omitted aspects. The design or construction of boats and other sea-faring vessels are also not referred to. A mention in this respect may, however, be made of an observation made by Solvyns in the *Les Hindous*. Introducing the 40 or so sketches of boats and river vessels in use in Northern India in the 1790s, he observed: 'The English, attentive to everything which relates to naval architecture, have borrowed from the Hindoos many improvements which they have adapted with success to their own shipping.'[48] Commenting on Indian rowing, an early eighteenth century observer remarked: 'Their water-men row after a different manner from ours. They move the oar with their feet, and their hands serve instead of the *hypomochlion*, or roller on which it turns.'[49]

It is not as if nothing at all is known of the various accounts reproduced in this volume. Chapters I, II, V and VI dealing with astronomy and mathematics are perhaps known to many concerned scholars. The accounts dealing with the manufacture of paper, the composition of the 'Madrass Mortar' and Iron Works at Ramanakapettah are possibly known to a still wider circle. Even the practice of inoculation against the smallpox is known to have existed in ancient times in India, for, according to one modern writer: 'Preventive inoculation against the smallpox, which was practised in China from the eleventh century, apparently came from India.'[50] Something also seems to be known about the manufacture of iron and steel in Salem through the writings about it by Campbell, the Assistant Surveyor General, Madras. Ranade himself seems to have been fairly well informed about the export of *wootz* to England and other countries, though he leaves the time vague

But all this knowledge among the scholars and prominent writers on Indian economics has not so far created any general awareness of the teaching and practice of these sciences and technologies, or the questioning of the prevailing hypothesis of 'the eighteenth century' being 'the darkest period' in Indian history,[51] etc. The reasons for the lack of appropriate awareness or the prevailing indifference are manifold. Primarily the responsibility for such a situation lies with the system of education which has prevailed in independent India, which by nurturing indifference, even contempt, for everything indigenous effectively blocks such enquiries.

The intellectual basis of the contempt and indifference which began to grow around the close of the eighteenth century, is perhaps best illustrated by the article on 'Algebra' in the *Encyclopaedia Britannica*, in its 8th edition (1850). Discussing Indian Algebra, it referred to a review by Prof John Playfair, of Colebrooke's work on Indian Algebra, and observed:

> This last article, published in 1817, may be supposed to contain the matured opinions of one of the most ardent, able, and we must say most candid, enquirers into the history of Hindoo mathematical science. There is here certainly an abatement of his first confidence in the opinion of Bailly on the Indian astronomy, and a corresponding caution in his own opinion as to the antiquity of the mathematical sciences. The very remote origin of the Indian Astronomy had been strongly questioned by many in this country, and also on the Continent; particularly by Laplace, also by Delambre in his *Histoire de l'Astronomie Ancienne*, tome i.p.400, & c., and again *Histoire de l'Astronomie du Moyen Age*, *Discourse Preliminaire*, p.8, & c., where he speaks slightingly of their algebra.

The article added: 'And in this country, Prof. Leslie, in his very learned work on *The Philosophy of Arithmetic*, pp.225 and 226, calls the *Lilavati* "a very poor performance, containing merely a few scanty precepts couched in obscure memorial verses".'

Playfair's observations, alluded to on this occasion, while differing from the views of Leslie etc., expressed some scholarly scepticism of the Indians' capacity in mathematical sciences. He had said:

> Among many subjects of wonder which the study of these ancient fragments cannot fail to suggest, it is not one of the

> least that algebra has existed in India, and has been cultivated for more than 1200 years, without any signal improvement, or the addition of any material discovery. The works of the ancient teachers of science have been commented on, elucidated, and explained with skill and learning; but no new methods have been invented, nor any new principle introduced. The method of resolving indeterminate problems, that constitute the highest merit of their analytical science, were known to Brahmagupta hardly less accurately than to Bhascara; and they appear to have been understood even by Aryabhata, more ancient by several centuries than either. A long series of scholiasts display in their annotations great acuteness, intelligence, and judgement; but they never pass far beyond the line drawn by their predecessors, which probably seemed even to those learned and intelligent men as the barrier within which it was to be confined. In India, indeed, everything seems equally insurmountable, and truth and error are equally assured of permanence in the stations they have once occupied. The politics, the laws, the religion, the science, and the manners, seem all nearly the same as at the remotest period to which history extends. Is it because the power which brought about a certain degree of civilisation, and advanced science to a certain height, has either ceased to act, or has met with such a resistance as it is barely able to overcome? Or is it because the discoveries which the Hindoos are in possession of are an inheritance from some more inventive and more ancient people, of whom no memorial remains but some of their attainments in science?[52]

The choice of this passage during the 1850s by the *Encyclopaedia Britannica* was in keeping with the sentiments of the period. But the 24 page unsigned article in the *Edinburgh Review* (Nov. 1817), from which this sceptical passage is taken, had also said many other things. Earlier in the article, Playfair observed:

> A commentary on the *Vija Ganita*, bearing the date of 1602, contains a full exposition of the sense, with complete demonstrations of the rules, much in the manner of Ganesa; and there is a scholiast of a still later date, who appears to have flourished about the year 1621. If, therefore, it be true, that the Hindus of the present time understand nothing

> of their scientific books the decline of knowledge among them must have been very rapid, as it is plain that, at the distance, of less than two centuries from the present time, the light of science was shining in India with considerable lustre.

Proceeding further while deploring the lack of 'analysis' even in the *Vija Ganita*, he noted that Brahmagupta had given 'a solution that appears quite general' concerning 'Indeterminate Problems'. And he observed: 'The solution then of a very difficult problem given by an Indian Algebraist, more than 1200 years ago, is such as can vie with those of two of the mathematicians the most distinguished for genius and invention which Europe could boast of ever having seen, at the end of the eighteenth century.' Dismissing that the finding of such a solution by Brahmagupta may have been due to chance, he added, 'there are inquiries where chance and accident have great influence and where a man of very inferior genius and knowledge may make great discoveries. But the subject we are treating of here, is not of that number; it is one where no one *finds*, who does not know how to *search*; and where there is no reward but for intense thought, and patient inquiry.'

Given the doubts of academicians like Playfair, Laplace, Delambre, etc., as well as the supporting role of the fast multiplying tribe of 'oriental scholars' amongst the servants of the British authorities in India (including those amongst the missionaries), Macaulay's verdict on Indian sciences and learning was inevitable. Only Macaulay expresses such doubts and contempt with greater drama and bombast. But what he said, in his minute of 2 February 1835, was shared fully not only by the then British Governor General of India, Bentinck ('I give my entire concurrence to the sentiments expressed in this minute'), but practically by every other learned or powerful European. Referring to the orientalists Macaulay observed:

> I have never found one amongst them who could deny that a single shelf of a good European library was worth the whole native literature of India and Arabia. The intrinsic superiority of the western literature is indeed fully admitted by those members of the committee [of Public Instruction] who support the oriental plan of education.

And then he added:

> It will hardly be disputed, I suppose, that the department of literature in which the Eastern writers stand highest is

> poetry. And I certainly never met with any orientalist who ventured to maintain that the Arabic and Sanskrit poetry could be compared to that of the great European nations. But when we pass from works of imagination to works in which facts are recorded and general principles investigated, the superiority of the Europeans becomes absolutely immeasurable. It is, I believe, no exaggeration to say that all the historical information which has been collected from all the books written in the Sanskrit language is less valuable than what may be found in the most paltry abridgement used at preparatory schools in England. In every branch of physical or moral philosophy the relative position of the two nations is nearly the same.

Concluding, Macaulay refused to associate himself with any support or assistance to Indian learning and declaimed:

> If on the other hand, it be the opinion of the Government that the present system ought to remain unchanged, I beg that I may be permitted to retire from the chair of the committee. I feel that I could not be of the smallest use to them. I feel also that I should be lending my countenance to what I firmly believe to be a mere delusion. I believe that the present system tends not to accelerate the progress of truth but to delay the natural death of expiring errors. I conceive that we have at present no right to the respectable name of a Board of Public Instruction. We are a Board for wasting the public money, for printing books which are of less value than the paper on which they are printed was while it was blank,—for giving artificial encouragement to absurd history, absurd metaphysics, absurd physics, absurd theology,—for raising up a breed of scholars who find their scholarship an encumbrance and a blemish, who live on the public while they are receiving their education, and whose education is so utterly useless to them that, when they have received it, they must either starve or live on the public all the rest of their lives. Entertaining these opinions I am naturally desirous to decline all share in the responsibility of a body which, unless it alters its whole mode of proceedings, I must consider not merely as useless, but as positively noxious.[53]

Remarks, observations, threats and declamations, like those quoted above, have shaped all the writing and teaching about India, and more or less continue to do so, in the manner and direction indicated by Macaulay and by his more (though less known in India) powerful precursors like William Wilberforce and James Mill.[54] Ignorance, apathy and utter mental confusion, particularly about life and society in the eighteenth century not only in India but in West Europe itself, are the natural products of such writing and teaching.

The doubts and declamations (of Playfair, Laplace, Macaulay, etc.), however, are not the sole causes of this ignorance and apathy. These seem to arise, partly, from much deeper issues which pertain to the conflicting hypotheses about state and society. The seventeenth, eighteenth and nineteenth centuries' European view of society, and thus of science, technology, politics, etc., was diametrically at variance with the views about them held by non-European societies during the same period.

Consequently, the sciences and technologies of the non-European world also had different seekings and developments to those of Europe. Further, in countries like India, their organisation was in tune with their more decentralist politics and there was no seeking to make their tools and work places unnecessarily gigantic and grandiose. Smallness and simplicity of construction, as of the iron and steel furnaces or of the drill ploughs, was in fact due to social and political maturity as well as arising from understanding of the principles and processes involved. Instead of being crude, the processes and tools of eighteenth century India appear to have developed from a great deal of sophistication in theory and a heightened sense of the aesthetic.

It is in such a context that a man like Voltaire considered India 'famous for its laws and sciences', and deplored the mounting European preoccupation (both individual and national) of those in India with the amassing of 'immense fortunes'. This quest for riches intensified the struggles, plunder, etc., during his own time, and made him remark: 'If the Indians had remained unknown to the Tartars and to us, they would have been the happiest people in the world.'[55] Looking back at what has happened since he wrote these lines, Voltaire seems to have been very perceptive in his judgment. But the whole world, if such contacts had not occurred, would have been very different not only in politics and society but also in science and technology. Speculations about what it may have been, though fascinating, are far beyond the scope of this volume.

A question yet remains: Why have sciences and technologies—which seem to have been very much alive about 8-10 generations ago—been wholly eclipsed? Answers about the causes of such an eclipse are very complex. Some of them are also—till there is systematic and detailed research available about Indian science and society—largely speculative. A few of them may, however, be suggested here.

The first is related to the economic breakdown of India during 1750-1900.

We may argue about the nature and intensity of exploitation of the agricultural and manufacturing population, or about the question of what happened to the money and goods extorted (the 50 per cent of the gross agricultural product compulsorily taken as governmental land revenue is a good example). But there can be no dispute that the breakdown of the economy was overwhelming and total. No sciences or technologies can survive intact such catastrophe.

The second point relates to the contrary nature of the new state fiscal system when compared with the indigenous system (or systems) prevailing at the commencement of the European impact. It seems that the indigenous budgeting of state revenues (whether for larger or smaller political entities and through various in-built devices) left the overwhelming proportion of revenue at the local levels.

The British-created fiscal system, on the other hand, doubled or trebled the rates of various assessments and effectively brought all people under its sway; taking away the overwhelming proportions to the central exchequers as well as to the metropolises and places above them. Studied neglect and contempt added to the economic breakdown and the transformation of the fiscal system. This to my mind completed the uprooting and elimination of indigenous sciences and technologies not only from society but from Indian memory itself.

Finally, the notion that all these sciences and technologies have wholly disappeared is not altogether true. Remnants of many still exist and continue to be of use; but, at a most neglected and impoverished level. For instance, it is said that some aspects of indigenous plastic surgery were being practised till fairly recently in places as far apart as Kangra and Junagadh.[56]

There are many philosophical formulations regarding the growth and decline of human societies (or the various stages which they are supposed to pass through). The theory of atrophy (as usually applied to India) is one of them. It is possible that it also has some relevance in explaining the growth, flowering and decline of Indian society. Though the contemporary data, as separate from opinions and formulations, does not seem to indicate that the eighteenth century sciences and technologies in India had atrophied, some of them may well have been in such a state. It is possible that various other current or past formulations on the subject of growth and decline of human societies also have some contribution to make in explaining what happened to Indian science and society over the millennia.

Whatever may be the actual relevance of the theory of atrophy or other theories of European origin in explaining the development of Indian society, it appears much more probable that in most respects the sciences and technologies of India had reached a desirable balance and equilibrium much before the eighteenth century. In the context of the values and aptitudes of Indian culture and social norms (and the consequent political structure and institutions), the sciences and technologies of India, instead of being in a state of atrophy, were in actuality usefully performing the tasks desired by Indian society. It is the application of unrelated standards and judgments (particularly those emanating from eighteenth-nineteenth century Europe) which hide and distort the actual situation and relationship.

V

Although organisationally weak in a military-political sense, in most respects the political and social ideas of India (like its legal and administrative arrangements as well as sciences and technologies) had achieved maturity and balance at some time previous to its present day contacts with the European world. Its social and political structure at this period, though seemingly different from those that obtain in the European world of today, was able to provide of freedom, well-being and social security basically similar to those at present available in much of the European world. It also seems to have had somewhat similar ideas about ruler-ruled relationship, the resolution of disputes, legal punishments, sexual mores, protests against those in authority, etc. But while the whole led to more freedom and equality, these characteristics added to a basically decentralised political and military structure and contributed to this society becoming more prone to external attack.

During the centuries, particularly between the twelfth and seventeenth, there is no dearth of such external onslaughts. The onslaughts to an extent are absorbed and accommodated by Indian society. Over a time, however, they contribute not only to further political and military weakness, but also to damaging the various integrating factors which had provided the necessary intellectual and spiritual links between different regions and specialist as well as ethnic groups. Over all, however, though considerably weaker and perhaps also psychologically at a low ebb, the major arrangements and expressions continued to serve the physical, social and spiritual needs of the Indian people satisfactorily.

At the time of the European onslaught, the indigenous tendencies in India seem to have been in a state of slow resurgence. The resurgence, while it restored a measure of confidence, weakened at the same time the political and military structure. With the beginning of European dominance in India, the resurgence got transformed into depression and unimaginable disorganisation. Foreign aggression and dominance was not wholly unknown in India before the resort to it by Europe in the mid-eighteenth century. But the Europeans of this period belonged to a wholly alien world in relation to India. They were not only armed with the concepts and hierarchical institutions of a long feudal European past, but had also been preparing for the occasion for two to three centuries. The subsequent application of their concepts and values completed the destruction of Indian science and society which had been started by the political and military defeat of India at their hands.

What has developed in India in the field of science and technology during the past century, and at a greater pace since 1947, is mainly a transplanting of some of that which has developed during this period in the European world. Such transplanting has happened not only at the level of theories, but even more so as regards the organisation of technology and the direction of research. It is largely due to such transplanting and its unthinking acceptance that, though many individual Indian scientists and technologists are as creative and inventive as their colleagues in the European world, the impact of this science and technology on the larger society of India is in fact minimal. It is no exaggeration, perhaps, to add that the field of science and technology in India, as far as it concerns its ordinary life, is only a little less barren than India's state system and its politics.

Borrowing of ideas and practices in themselves need not be obstructive to India's development or creativity. During the centuries, India must have borrowed many ideas and practices from other lands—in the same manner in which Europe received much in the field of science and technology from the Arabs etc., or the Arabs and others did from India. To the extent that such borrowings lead to further innovation and creativity, they are to be greatly welcomed. Unfortunately, so far, the past century's unthinking transplanting of European sciences and technologies in India has resulted mainly in retarding and blunting of indigenous innovation and creativity.

The problem for India today, as perhaps for many other lands which are still recovering from the effects of eighteenth and nineteenth century European dominance, is how to achieve and increase such innovation and creativity. Such innovation and creativity can arise, however, only from a widespread indigenous base. Such a base has yet to be identified (and the superstructure accordingly modified and linked with it) in countries like India. For that, knowledge and comprehension of how they functioned before the beginning of this dominance seem to be essential. Even for the purposeful adaptations from European (or for that matter Japanese, Chinese or any other) science and technology and their integration with indigenous concepts, knowledge and forms, it is necessary that these countries achieve such self-knowledge and understanding at the earliest possible.

Notes

1. Lady Mary Wortley Montagu: *Memoirs.*
2. See mid-eighteenth century *Tracts on Inoculation* in the British Museum
3. *Encyclopaedia Britannica*: 1910-11 edition: Article on *Sowing.*
4. See Chapter II, p.89.
5. *Edinburgh Review*, Vol.22, Jan. 1814, pp.474-75
6. See Chapter II, p.51.
7. *Encyclopaedia Britannica*: 1823 edition: Article on *Hindoos*, Vol.X, p.477.
8. *Edinburgh Review*, Vol.X (1810), p.387; also see 'An Essay on the Sacred Isles in the West' by Francis Wilford in the *Asiatic Researches*, Vol.8 (1808), pp.246-7.
9. *Philosophical Transactions*, Vol.83 (1793), Article by John Lloyd Williams, pp.45-9.

10. *Asiatic Researches*, Vol.5 (1798), Article by W. Hunter, pp.177-211.

11. *Ibid.*

12. G.R. Kaye (honorary correspondent of Archaeological Department of India), Calcutta, Government Printing Press, 1920.

13. *Ibid.*

14. J.P. Tavernier: *Travels in India*, Calcutta, 1905, p.425.

15. Bengal: Past and Present, Vol.6, pp.279-80

16. *Encyclopaedia Britannica*: 8th Edition (1850), Article on *Algebra*.

17. *Encyclopaedia Britannica*: 11th Edition (1910-11), Article on *Binomial Theorem.*

18. *Asiatic Researches*, Vol.13 (1820), Article by R. Tytler, M.D., pp.456-67.

19. *Ibid.*

20. See Chapter VI, p.146.

21. India Office Records (IOR): *MSS Eur F/95/I*, 'Some Remarks on the Soil and Cultivation on the Western Side of the River Hooghly', ff.81r.

22. See Chapter XVII, pp.255.

23. *Ibid*, pp.256.

24. Report on the Progress of Vaccine Inoculation in Bengal, Calcutta, 1804.

25. *Ibid*, p.27-8.

26. *Ibid*, p.94.

27. See *Tracts on Inoculation*, referred to above (reference 2) for the theological reasons advanced against inoculation in Britain in the eighteenth century.

28. IOR: Practice of Inoculation in the Benares Division: From Officiating Superintendent General of Vaccination to Government N.W.P., dated 6th June 1870, p.77.

29. Ibid, Report by R.M. Milne, Officiating Superintendent of Vaccination, dated 1st April 1870, p.72.

30. See Chapter VIII, p.161.

31. See Chapter XII, p.191.

32. Rameshchandra Majumdar, H.C. Raychaudhuri, Kalikinkar Datta: *An Advanced History of India*, 3rd edition (1967), p.564.

33. *Philosophical Transactions*, Vol.65 (1775), Article by Joseph Black, M.D., pp.124-8.

34. See Chapter XVII, p.258.

35. *Philosophical Transactions*, Vol.85 (1795), 'Experiments and Observations to investigate the Nature of a Kind of Steel, manufactured at Bombay, and there called Wootz: with Remarks on the Properties and Composition of the different States of Iron', by. George Pearson, M.D., F.R.S., pp.322-346. See also D. Mushet: *Experiments on Wootz or Indian Steel* (British Museum 727. k.3), pp.650-62.

36. Stodart to B. Heyne: Quoted in Heyne's *Tracts on India*, 1814, p.363. According to Robert Hadfield, Stodart was probably 'the same Mr Stodart who many years later assisted Faraday in preparing and investigating a large number of steel alloys' (*Journal of Iron and Steel Institute*, Vol.85). According to Heyne, Stodart was 'an eminent instrument-maker', and according to Pearson, whom he assisted in conducting the experiments on Wootz in 1794-5, Stodart was an 'ingenious artist'.

37. *Ibid*, p.364.

38. *Philosophical Transactions*, Vol.85, Pearson's Experiments, p.345.

39. J.M. Heath: 'On Indian Iron and Steel' quoted in D. Mushet, *Ibid*, p.671.

40. *Ibid.*

41. *lbid.*

42. *lbid*, p.669, 671.

43. See, for instance, an English version of D. Havart's *Rise and Decline of Coromandel* (from the original Dutch published in 1692 or 1693, from Utrecht), pp.291-94, 401-3, in *Mackenzie MSS (Private)*, Vol.88, in IOR.

44. M.G. Ranade: *Essays on Indian Economics*, 3rd edition, 1916, p.155.

45. See Chapter XV, p.215.

46. National Archives of India (NAI): HOME, Misc. Records, Vol.437, *Report of the Mineralogical Survey of the Himalaya Mountains, 1826*, p.627.

47. IOR: Public Despatch to Bengal, July 29, 1814, para 9.

48. Francois Baltazar Solvyns: *Les Hindous*, 4 Vols, 1802-12.

49. *Philosophical Transactions*, Vol.28, from Fr Papin, Bengale, December 18, 1709, p.226.

50. Kurt Pollak: *The Healers: The Doctor, Then and Now*, English Edition 1968, pp.37-8.

51. Majumdar and others: *An Advanced History of India*, p.561.

52. *Encyclopaedia Britannica*: 8th edition, Article on Algebra.

53. NAI: India Public Proceedings, March 7, 1835, Minutes on Public Instruction.

54. See, amongst others, *Speeches of William Wilberforce on India in the British House of Commons in 1813*, also James Mill's *History of British India*, 1817, particularly Vol.I.

55. Voltaire: *Collected Works*, Vol.38 (BM 1341 d 8), pp.83-4, 87.

56. See S.C. Almast 'History and Evolution of Indian Method of Rhinoplasty', in Proceedings of Fourth International Congress on Plastic Surgery, Rome, 1967, Excerpta Medica Foundation, Amsterdam, 1969.

PART I

SCIENCE

I

BRAMIN'S OBSERVATORY AT BENARES

Benares (By Sir Robert Barker, F.R.S. (Published 1777).) in the East Indies, one of the principal seminaries of the Bramins or priests of the original Gentoos of Hindostan, continues still to be the place of resort of that sect of people; and there are many public charities, hospitals, and pagodas, where some thousands of them now reside. Having frequently heard that the ancient Bramins had a knowledge of astronomy, and being confirmed in this by their information of an approaching eclipse both of the Sun and Moon, I made inquiry, when at that place in the year 1772, among the principal Bramins, to endeavour to get some information relative to the manner in which they were acquainted of an approaching eclipse. The most intelligent that I could meet with, however, gave me but little satisfaction. I was told, that these matters were confined to a few, who were in possession of certain books and records; some containing the mysteries of their religion, and others the tables of astronomical observations, written in the Sanskrit language, which few understood but themselves: that they would take me to a place which had been constructed for the purpose of making such observations as I was inquiring after, and from whence they supposed the learned Bramins made theirs. I was then conducted to an ancient building of stone, the lower part of which, in its present situation, was converted into a stable for horses, and a receptacle for lumber; but, by the number of courtyards and apartments, it appeared that it must once have been an edifice for the use of some public body of people. We entered this building, and went up a staircase to the top of a part of it, near to the river Ganges, that led to a large terrace, where, to my surprise and satisfaction, I saw a number of instruments yet remaining, in the greatest preservation, stupendously large, immoveable from the spot, and built of stone, some of them being upwards of twenty feet in height; and, although they are said to have been erected two hundred years ago, the graduations and divisions on the several arcs appeared as well cut, and as accurately divided, as if they had been the performance of a modern artist. The execution in the construction of these instruments exhibited a mathematical exactness in the fixing, bearing, and fitting of the several parts, in the necessary and sufficient supports to the very large stones that composed them, and in the joining and fastening each into the other by means of lead and iron.

The situation of the two large quadrants of the instrument marked *A* in *Figure I,* whose radius is nine feet two inches, by their being at right angles with a gnomon at twenty-five degrees elevation, are thrown into such an oblique situation as to render them the most difficult, not only to construct of such a magnitude, but to secure in their position for so long a period, and affords a striking instance of the ability of the architect in their construction; for, by the shadow of the gnomon thrown on the quadrants, they do not appear to have altered in the least from their original position; and so true is the line of the gnomon, that, by applying the eye to a small iron ring of an inch diameter at one end, the sight is carried through three others of the same dimension to the extremity at the other end, distant thirty-eight feet eight inches, without obstruction; such is the firmness and art with which this instrument has been executed. This performance is the more wonderful and extraordinary when compared with the works of the artificers of Hindostan at this day, who are not under the immediate direction of an European mechanic; but arts appear to have declined equally with science in the East.

Lieutenant-colonel Archibald Campbell, at that time chief engineer in the East India Company's service at Bengal, a gentleman whose abilities do honour to his profession, made a perspective drawing of the whole of the apparatus that could be brought within his eye at one view; but I lament he could not represent some very large quadrants, whose radii were about twenty feet, they being on the side from whence he took his drawing. Their description however is, that they are exact quarters of circles of different radii, the largest of which I judged to be twenty feet, constructed very exactly on the sides of stone walls built perpendicular, and situated, I suppose, in the meridian of the place: a brass pin is fixed at the center or angle of the quadrant, from whence, the Bramin informed me, they stretched a wire to the circumference when an observation was to be made; from which it occurred to me, the observer must have moved his eye up or down the circumference, by means of a ladder or some such contrivance, to raise and lower himself, until he had discovered the altitude of any of the heavenly bodies in their passage over the meridian, so expressed on the arcs of these quadrants: these arcs were very exactly divided into nine large sections; each of which again into ten, making ninety lesser divisions or degrees: and those also into twenty, expressing three minutes each, of about two-tenths of an inch asunder; so that it is probable, they had some method of dividing even these into more minute divisions at the time of observation.

My time would only permit me to take down the particular dimensions of the most capital instrument, or the greater equinoctial Sun-dial, represented by *Figure I, A,* which appears to be an instrument to express solar time by the shadow of a gnomon upon two quadrants, one situated to the east, and the other to the west of it; and indeed the chief part of their instruments at this place appear to be constructed for the same purpose, except the quadrants, and a brass instrument that will be described hereafter.

Figure I, B, is another instrument for the purpose of determining the exact hour of the day by the shadow of a gnomon, which stands perpendicular to and in the center of a flat circular stone, supported in an oblique situation by means of four upright stones and a cross-piece; so that the shadow of the gnomon, which is a perpendicular iron rod, is thrown upon the divisions of the circle described on the face of the flat, circular stone.

Figure I, C, is a brass circle, about two feet in diameter, moving vertically upon two pivots between two stone pillars, having an index or hand turning round horizontally on the center of this circle, which is divided into 360 parts; but there are no counter-divisions on the index to sub-divide those on the circle. This instrument appears to be made for taking the angle of a star at setting or rising, or for taking the azimuth or amplitude of the Sun at rising or setting.

The use of the instrument, *Figure I, D,* I was at a loss to account for. It consists of two circular walls; the outer of which is about forty feet diameter, and eight feet high; the wall within about half that height, and appears intended for a place to stand on to observe the divisions on the upper circle of the outer wall, rather than for any other purpose; and yet both circles are divided into 360 degrees, each degree being sub-divided into twenty lesser divisions, the same as the quadrants. There is a

doorway to pass into the inner circle, and a pillar in the center, of the same height with the lower circle, having a hole in it, being the center of both circles, and seems to be a socket for an iron rod to be placed perpendicular into it. The divisions on these, as well as all the other instruments, will bear a nice examination with a pair of compass.

Figure I, E, is a smaller equinoctial Sun-dial, constructed upon the same principle as the large one *A*.

I cannot quit this subject without observing, that the Bramins, without the assistance of optical glasses, had nevertheless an advantage unexperienced by the observers of the more Northern climates. The serenity and clearness of the atmosphere in the night-time in the East Indies, except at the seasons of changing the monsoons or periodical winds, is difficult to express to those who have not seen it, because we have nothing in comparison to form our ideas upon: it is clear to perfection, a total quietude subsists, scarcely a cloud to be seen; and the light of the heavens, by the numerous appearance of the stars, affords a prospect both of wonder and contemplation.

This observatory at Benares is said to have been built by the order of the emperor Ackbar; for as this wise prince endeavoured to improve the arts, so he wished also to recover the sciences of Hindostan, and therefore directed that three such places should be erected; one at Delhi, another at Agra, and the third at Benares.

Some doubts have arisen with regard to the certainty of the ancient Bramins having a knowledge in astronomy, and whether the Persians might not have introduced it into Hindostan, when conquered by that people; but these doubts I think must vanish, when we know that the present Bramins pronounce, from the records and tables which have been handed down to them by their forefathers, the approach of the eclipses of the Sun and Moon, and regularly as they advance give timely information to the emperor and the princes in whose dominion they reside. There are yet some remains in evidence of their being at one time in possession of this science. The signs of the Zodiac, in some of their Choultrys on the coast of Coromandel, as remarked by John Call, Esq. F.R.S. in his letter to the Astronomer Royal, requires little other confirmation. Mr Call says, that as he was laying on his back, resting himself in the heat of the day, in a Choultry at Verdapetah in the Madura country, near Cape Commorin, he discovered the signs of the Zodiac on the ceiling of the Choultry: that he found one, equally complete, which was on the ceiling of a temple, in the middle of a tank before the pagoda Teppecolum near Mindurah; and that he had often met with several parts in detached pieces. (See *Philos. Trans.* 1772, p.353) These buildings and temples were the places of residence and worship of the original Bramins, and bear the marks of great antiquity, having perhaps been built before the Persian conquest. Besides, when we know that the manners and customs of the Gentoo religion are such as to preclude them from admitting the smallest innovation in their institutions; when we also know that their fashion in dress, and the mode of their living, have not received the least variation from the earliest account we have of them; it cannot be supposed they would engrave the symbolical figures of the Persian astronomy in their sacred temples; the signs of the Zodiac must therefore have originated with them, if we credit their tradition of the purity of their religion and customs.

Mr Fraser in his History of the Mogul Emperors, speaking of time says, 'the Lunar year they reckon 354 days, 22 gurris, 1 pull; the Solar year they reckon 365 days, 15 gurris, 30 pulls, 22½ peels; 60 peels making 1 pull, 60 pulls 1 gurri, and 60 gurris 1 day. This is according to the Bramins or Indian priests, and what the Moguls and other Mahommedans in India chiefly go by.'

Thus far Mr Fraser; and it serves to strengthen the argument for supposing that the Bramins had a knowledge of astronomy before the introduction of Mahommedanism into Hindostan.

Dimensions of the Larger Equinoctial Sun-dial
(Figures II and III)

	Feet	In.
Length of the gnomon at the base *b b*,	34	8
Oblique length of the gnomon *c c*,	38	8
Radius of the quadrants *a a*,	9	2
Height of the gnomon at *d*,	22	3
Breadth of the quadrants *f f*,	5	10
Thickness *g g*,	1	0
Breadth of the gnomon *b b*,	4	6
Whole extent of the instrument *i i*,	37	4

Latitude of the place taken by double altitude 25°10'.

Supplementary Note (**By Colonel T.D. Pearse (who accompanied Sir Robert Barker) to General Desaguliers.**)

The principal curiosity here is the observatory, built by Mawnsing, the son of Jysing, about 200 years ago; there is an exceedingly good mural arch cut upon a fine plaister of chunam, so fine and smooth, that it has the appearance of marble; and though it is certainly very old, it still is perfect, but the index is wanting; that is a loss which could very easily be supplied by a person who has a taste for these studies; for the centres are left in the wall.

There are two ring dials; the large one is curious: the radius of the stone arch is 9 feet 8 inches; the gnomon is 4 feet 6 inches thick, and its slant side about 40 feet long: there are steps in the gnomon by which you ascend to the top of it. By the measure of the two gnomons, I find they stand in latitude 25° 20′ N. There are likewise two small inclined dials, in which the gnomon is perpendicular to the plane of the stone on which the degrees are marked. Lastly, there is an instrument which I do not understand, the following is a description of it:

A, b are circular walls; *a* is 24 inches thick, and near 16 feet radius; *b* is concentric with *a*, 18 inches thick, and between 12 and 13 feet radius. *C* is a cylinder of stone, its center is the center of the walls. *B* and *C* are of equal height, viz, 4 feet 2 inches; the outward wall is 8 feet and 4 inches. The tops of these walls are horizontal, and are very nicely divided into degrees, and subdivided into arches of 6′. At the cardinal points on the top of the wall *a*; there are two iron pins, from which I conjecture there has been an instrument to fix upon the wall, though I do not know for what purpose or of what kind.

Lastly the second, for I had forgotten an instrument for taking the declension of the sun, etc., which consists of a circle of iron, covered with brass, an axis of the same materials, and an index with sights. This axis, which is a diameter of a circle, and consequently in the plane of it, moves on pivots fixed in the walls, which support it and is parallel to the axis of the earth. The divisions are very much inferior to those on the stone.

II

REMARKS ON THE ASTRONOMY OF THE BRAHMINS

(By John Playfair, A.M., F.R.S., Edin. (Published 1790).)

Since the time when astronomy emerged from the obscurity of ancient fable, nothing is better known than its progress through the different nations of the earth. With the era of Nabonassar, regular observations began to be made in Chaldea; the earliest which have merited the attention of succeeding ages. The curiosity of the Greeks was, soon after, directed to the same object; and that ingenious people was the first that endeavoured to explain, or connect by theory, the various phenomena of the heavens. This work was supposed to be so fully accomplished in the Syntaxes of Ptolemy that his system, without opposition or improvement, continued, for more than five hundred years, to direct the astronomers of Egypt, Italy and Greece. After the sciences were banished from Alexandria, his writings made their way into the East, where, under the Caliphs of Bagdat, astronomy was cultivated with diligence and success. The Persian princes followed the example of those of Bagdat, borrowing besides, from Trebisond, whatever mathematical knowledge was still preserved among the ruins of the Grecian empire. The conquests of Gengis, and afterwards of Timour, though they retarded, did not stop the progress of astronomy in the East. The grandsons of these two conquerors were equally renowned for their love of science: Hulagu restored astronomy in Persia, and Ulugh-Beigh, by an effort still more singular, established it in Tartary. In the meantime, having passed with the Arabs into Spain, it likewise found, in Alphonso of Castile, both a disciple and a patron. It was carried, soon after, into the north of Europe, where, after exercising the genius of Copernicus, of Kepler, and of Newton, it has become the most perfect of all the sciences.

2. In the progress which astronomy has thus made, through almost all the nations, from the Indus to the Atlantic, there is scarce a step which cannot be accurately traced; and it

is never difficult to determine what each age, or nation received from another, or what it added to the general stock of astronomical knowledge. The various systems, that have prevailed in all these countries, are visibly connected with one another; they are all derived from one original, and would incline us to believe, that the manner in which men begin to observe the heavens, and to reason about them, is an experiment on the human race, which has been made but once.

It is, therefore, matter of extreme curiosity to find, beyond the Indus, a system of astronomical knowledge that appears to make no part of the great body of science, which has traversed, and enlightened the other countries of the earth; a system that is in the hands of men, who follow its rules without understanding its principles, and who can give no account of its origin, except that it lays claim to an antiquity far beyond the period, to which, with us, the history of the heroic ages is supposed to extend.

3. We owe our first knowledge of this astronomy to M. La Loubere, who, returning, in 1687, from an embassy to Siam, brought with him an extract from a Siamese manuscript, which contained tables, and rules, for calculating the places of the sun and moon.[1] The manner in which these rules were laid down, rendered the principles, on which they were founded, extremely obscure; and it required a commentator, as conversant with astronomical calculation as the celebrated Cassini, to explain the meaning of this curious fragment. After that period, two other sets of astronomical tables were sent to Paris, by the missionaries in Hindostan; but they remained unnoticed, till the return of M. Le Gentil from India, where he had been to observe the transit of Venus in 1769. This academician employed himself, during the long stay, which his zeal for science induced him to make in that country, in acquiring a knowledge of the Indian astronomy. The Brahmins thought they saw, in the business of an astronomer, the marks of a *cast*, that had some affinity to their own, and began to converse with M. Le Gentil, more familiarly than with other strangers. A learned Brahmin of Tirvalore, having made a visit to the French astronomer, instructed him in the methods, which he used for calculating eclipses of the sun and moon, and communicated to him the tables and rules, that are published in the Memoirs of the Academy of Sciences, for 1772. Since that time, the ingenious and eloquent author of the

History of Astronomy, has dedicated an entire volume to the explanation, and comparison of these different tables, where he has deduced, from them, many interesting conclusions.[2] The subject indeed merited his attention; for the Indian astronomy has all the precision necessary for resolving the great questions, with respect to its own origin and antiquity, and is by no means among the number of those imperfect fragments of ancient knowledge, which can lead no further than conjecture, and which an astronomer would gladly resign to the learned researches of the antiquary, or the mythologist.

4. It is from these sources, and chiefly from the elaborate investigations of the last mentioned work, that I have selected the materials of the paper, which I have now the honour to lay before this Society; and it is perhaps necessary that I should make some apology for presenting here, what can have so little claim to originality. The fact is, that notwithstanding the most profound respect, for the learning and abilities of the author of the *Astronomie Indienne*, I entered on the study of that work, not without a portion of the scepticism, which whatever is new and extraordinary in science ought always to excite, and set about verifying the calculations, and examining the reasonings in it, with the most scrupulous attention. The result was, an entire conviction of the accuracy of the one, and of the solidity of the other; and I then fancied, that, in an argument of such variety, I might perhaps do a service to others, by presenting to them, that particular view of it, which had appeared to me the most striking. Such, therefore, is the object of these remarks; they are directed to three different points: The first is to give a short account of the Indian astronomy, so far as it is known to us, from the four sets of tables above mentioned; the second, to state the principal arguments, that can be deduced from these tables, with respect to their antiquity; and the third, to form some estimate of the geometrical skill with which this astronomical system is constructed. In the first, I have followed M. Bailly closely; in the second, though I have sometimes taken a different road, I have always come to the same conclusion; having aimed at nothing so much, as to reduce the reasoning into a narrow compass, and to avoid every argument that is not purely astronomical, and independent of all hypothesis; in the third, I have treated of a question which did not fall within the plan of M. Bailly's work, but have only entered on it at present, leaving to some future opportunity, the other discussions to which it leads.

5. The astronomy of India, as you already perceive, is confined to one branch of the science. It gives no theory, nor even any description of the celestial phenomena, but satisfies itself with the calculation of certain changes in the heavens, particularly of the eclipses of the sun and moon, and with the rules and tables by which these calculations must be performed. The Brahmin, seating himself on the ground, and arranging his shells before him, repeats the enigmatical verses that are to guide his calculation, and from his little tablets of palm leaves, takes out the numbers that are to be employed in it. He obtains his result with wonderful certainty and expedition; but having little knowledge of the principles on which his rules are founded, and no anxiety to be better informed, he is perfectly satisfied, if, as it usually happens, the commencement and duration of the eclipse answer, within a few minutes, to his prediction. Beyond this his astronomical enquiries never extend; and his observations, when he makes any, go no farther than to determine the meridian line, or the length of the day, at the place where he observes.

The objects, therefore, which this astronomy presents to us, are principally three. 1. Tables and rules for calculating the places of the sun and moon; 2. Tables and rules for calculating the places of the planets; 3. Rules by which the phases of eclipses are determined. Though it is chiefly to the first of these that our attention at present is to be directed, the two last will also furnish us with some useful observations.

6. The Brahmins, like all other astronomers, have distinguished from the rest of the heavens, that portion of them, through which the sun, moon and planets continually circulate. They divide this space, which we call the Zodiac, into twenty-seven equal parts, each marked by a group of stars, or a constellation.[3] This division of the Zodiac is extremely natural in the infancy of astronomical observation; because the moon completes her circle among the fixed stars, nearly in twenty-seven days, and so makes an actual division of that circle into twenty-seven equal parts. The moon too, it must be remembered, was, at that time, the only instrument, if we may say so, by which the positions of the stars on each side of her path could be ascertained; and when her own irregularities were unknown, she was, by the rapidity of her motion eastward, well adapted for this purpose. It is also to the phases of the moon, that we are to ascribe the

common division of time into weeks, or portions of seven days, which seems to have prevailed almost over the whole earth.[4] The days of the week are dedicated by the Brahmins, as by us, to the seven planets, and what is truly singular, they are arranged precisely in the same order.

7. With the constellations, that distinguish the twenty-seven equal spaces, into which their Zodiac is divided, the astronomers of India, have connected none of those figures of animals, which are among us, of so ancient, and yet so arbitrary an origin. M. Le Gentil has given us their names, and configurations.[5] They are formed, for the most part, of small groups of stars, such as the Pleiades or the Hyades, those belonging to the same constellation being all connected by straight lines. The first of them or that which is placed at the beginning of their Zodiac, consists of six stars, extending from the head of Aries to the foot of Andromeda, in our Zodiac, and occupying a space of about ten degrees in longitude. These constellations are far from including all the stars in the Zodiac. M. Le Gentil remarks, that those stars seem to have been selected, which are best adapted for marking out, by lines drawn between them, the places of the moon in her progress through the heavens.

At the same time that the stars in the Zodiac are thus arranged into twenty-seven constellations, the ecliptic is divided, as with us, into twelve signs of thirty degrees each. This division is purely ideal, and is intended merely for the purpose of calculation. The names and emblems by which these signs are expressed, are nearly the same as with us;[6] and there is nothing in the nature of things to have determined this coincidence, it must, like the arrangement of the days of the week, be the result of some ancient and unknown communication.

8. That motion by which the fixed stars all appear to move eastward, and continually to increase their distance from the place, that the sun occupies at the vernal equinox, is known to the Brahmins, and enters into the composition of all their tables.[7] They compute this motion to be at the rate of 54″ a year; so that their *annus magnus*, or the time in which the fixed stars complete an entire revolution, is 24,000 years. This motion is too

uick by somewhat less than 4″ a year; an error that will not be thought great, when it is considered, that Ptolemy committed one of 14″, in determining the same quantity.

Another circumstance, which is common to all the tables, and, at the same time, peculiar to the Indian astronomy, is, that they express the longitude of the sun and moon, by their distance from the beginning of the moveable Zodiac, and not, as is usual with us, by their distance from the point of the vernal equinox. The longitude is reckoned in signs of 30°, as already mentioned, and each degree is subdivided into 60′, etc. In the division of time, their arithmetic is purely sexagesimal: They divide the day into 60 hours, the hour into 60 minutes, etc.; so that their hour is 24 of our minutes, their minute 24 of our seconds, and so on.

9. These remarks refer equally to all the tables. We are now to take notice of what is peculiar to each, beginning with those of Siam.

In order to calculate for a given time, the place of any of the celestial bodies, three things are required. The first is, the position of the body in some past instant of time, ascertained by observation; and this instant, from which every calculation must set out, is usually called the *epoch* of the tables. The second requisite is, the mean rate of the planet's motion, by which is computed the arch in the heavens, that it must have described, in the interval between the epoch and the instant for which the calculation is made. By the addition of this, to the place at the epoch, we find the mean place of the planet, or the point it would have occupied in the heavens, had its motion been subject to no irregularity. The third is, the correction, on account of such irregularity, which must be added to the mean place, or subtracted from it, as circumstances require, in order to have the true place. The correction thus made is, in the language of astronomy, called an equation; and, when it arises from the eccentricity of a planet's orbit, it is called the equation of the centre.

10. The epoch of the tables of Siam does not go back to any very remote period. M. Cassini, by an ingenious analysis of their rules, finds that it corresponds to the 21st of March, in the year 638 of our era, at 3 in the morning, on the meridian of Siam.[8] This was the instant at which the astronomical year began, and at which both the sun and moon entered the moveable Zodiac.

Indeed, it is to be observed, that, in all the tables, the astronomical year begins when the sun enters the moveable Zodiac, so that the beginning of this year is continually advancing with respect to the seasons, and makes the complete round of them in 24,000 years.

From the epoch above mentioned, the mean place of the sun for any other time is deduced, on the supposition that in 800 years, there are contained 292,207 days.[9] This supposition involves in it the length of the sydereal year, or the time that the sun takes to return to the beginning of the moveable Zodiac, and makes it consist of 365^d, 6^h, 12′, 36″.[10] From this, in order to find the tropical year, or that which regulates the seasons, we must take away 21′, 55″, as the time which the sun takes to move over the 54″, that the stars are supposed to have advanced in the year; there will remain 365^d, 5^h, 50′, 41″, which is the length of the tropical year that is involved, not only in the tables of Siam, but likewise, very nearly, in all the rest.[11] This determination of the length of the year is but 1′, 53″, greater than that of De La Caille, which is a degree of accuracy beyond what is to be found in the more ancient tables of our astronomy.

11. The next thing with which these tables present us, is a correction of the sun's mean place, which corresponds to what we call the equation of his centre, or the inequality arising from the eccentricity of his orbit, in consequence of which, he is alternately retarded and accelerated, his true place being, for one half of the year, left behind the mean, and, for the other, advanced before it. The point where the sun is placed, when his motion is slowest, we call his apogee, because his distance from the earth is then greatest; but the Indian astronomy, which is silent with respect to theory; treats this point as nothing more than what it appears to be, a point, viz. in the heavens, where the sun's motion is the slowest possible, and about 90° distant from that, where his greatest inequality takes place. This greatest inequality is here made to be 2°, 12′,[12] about 16′ greater than it is determined, by the modern astronomy of Europe. This difference is very considerable; but we shall find that it is not to

be ascribed wholly to error, and that there was a time when the inequality in question was nearly of the magnitude here assigned to it. In the other points of the sun's path, this inequality is diminished, in proportion to the sine of the mean distance from the apogee, that is, nearly as in our own tables. The apogee is supposed to be 80° advanced beyond the beginning of the Zodiac, and to retain always the same position among the fixed stars, or to move forward at the same rate with them.[13] Though this supposition is not accurate, as the apogee gains upon the stars about 10″ annually, it is much nearer the truth than the system of Ptolemy, where the sun's apogee is supposed absolutely at rest, so as continually to fall back among the fixed stars, by the whole quantity of the precession of the equinoxes.[14]

12. In these tables, the motions of the moon are deduced, by certain intercalations, from a period of nineteen years, in which she makes nearly 235 revolutions; and it is curious to find at Siam, the knowledge of that cycle, of which the invention was thought to do so much honour to the Athenian astronomer Meton, and which makes so great a figure in our modern kalendars.[15] The moon's apogee is supposed to have been in the beginning of the moveable Zodiac, 621 days after the epoch of the 21st of March 638, and to make an entire revolution in the heavens in the space of 3232 days.[16] The first of these suppositions agrees with Mayer's tables to less than a degree, and the second differs from them only by 11^{h}, 14′, 31″-; and if it be considered that the apogee is an ideal point in the heavens, which even the eyes of an astronomer cannot directly perceive, to have discovered its true motion, so nearly, argues no small correctness of observation.

13. From the place of the apogee, thus found, the inequalities of the moon's motion, which are to reduce her mean to her true place, are next to be determined. Now, at the oppositions and conjunctions, the two greatest of the moon's inequalities, the

equation of the centre and the evection, both depend on the distance from the apogee, and therefore appear but as one inequality. They also, partly, destroy one another; so that the moon is retarded or accelerated, only by their difference, which, when greatest, is according to Mayer's tables, 4°, 57′, 42″. The Siamese rules, which calculate only for oppositions and conjunctions, give, accordingly, but one inequality to the moon, and make it, when greatest, 4°, 56′, not 2′ less than the preceding. This greatest equation is applied, when the moon's mean distance from the apogee is 90°; in other situations, the equation is less, in proportion as the sine of that distance diminishes.[17]

14. The Siamese MS breaks off here, and does not inform us how the astronomers of that country proceed, in the remaining parts of their calculation, which they seem to have undertaken, merely for some purpose in astrology. M. Cassini, to whom we are indebted for the explanation of these tables, observes, that they are not originally constructed for the meridian of Siam, because the rules direct to take away 3′ for the sun, and 40′ for the moon, (being the motion of each for 1^h 13′), from their longitudes calculated as above.[18] The meridian of the tables is therefore 1^h, 13′ or 18°, 15′ west of Siam; and it is remarkable, that this brings us very near to the meridian of Benares, the ancient seat of Indian learning.[19] The same agrees nearly with what the Hindoos call their first meridian, which passes through Ceylon and the banks of Ramanancor. We are, therefore, authorised, or rather, we are necessarily determined to conclude, that the tables of Siam came originally from Hindostan.

15. Another set of astronomical tables, now in the possession of the Academy of Sciences, was sent to the late M. De L'Isle from Chrisnabouram, a town in the Caranatic, by Fr Du Champ, about the year 1750. Though these tables have an obvious affinity to what has already been described, they form a much more regular and extensive system of astronomical knowledge. They are fifteen in number; and include, beside the mean motions of the sun, moon and planets, the equations to the centre of the sun and moon, and two corrections for each of the planets, the one of which corresponds to its apparent, and the other to its real inequality. They are accompanied also with precepts,

and examples, which Fr Du Champ received from the Brahmins of Chrisnabouram, and which he has translated into French.[20]

The epoch of these tables is less ancient than that of the former, and answers to the 10th of March at sunrise, in the year 1491 of our era, when the sun was just entering the moveable Zodiac, and was in conjunction with the moon; two circumstances, by which almost all the Indian eras are distinguished. The places, which they assign, at that time, to the sun and moon, agree very well with the calculations made from the tables of Mayer, and De La Caille. In their mean motions, they indeed differ somewhat from them; but as they do so equally for the sun and moon, they produce no error, in determining the relative position of these bodies, nor, of consequence, in calculating the phenomena of eclipses. The sun's apogee is here supposed to have a motion swifter than that of the fixed stars, by about 1″ in nine years, which, though it falls greatly short of the truth, does credit to this astronomy, and is a strong mark of originality. The equation of the sun's centre is somewhat less here than in the tables of Siam; it is 2°, 10′, 30″; the equation of the moon's centre is 5°, 2′, 47″; her path, where it intersects that of the sun, is supposed to make an angle with it of 4°, 30′, and the motions, both of the apogee and node, are determined very near to the truth.

16. Another set of tables, sent from India by Fr Patouillet, were received by M. De L'Isle, about the same time with those of Chrisnabouram. They have not the name of any particular place affixed to them; but, as they contain a rule for determining the length of the day, which answers to the latitude of 16°, 16′, M. Bailly thinks it probable that they come from Narsapour.[21]

The precepts and examples, which accompany these tables, though without any immediate reference to them, are confined to the calculation of the eclipses of the sun and moon; but the tables themselves extend to the motion of the planets, and very much resemble those of Chrisnabouram, except that they are given with less detail, and in a form much more enigmatical.[22]

The epoch of the precepts, which M. Bailly has evolved with great ingenuity, goes back no farther than the year 1569, at midnight, between the 17th and 18th of March. From this epoch, the places of the sun and moon are computed, as in the tables of Siam, with the addition of an equation, which is indeed extremely singular. It resembles that correction of the moon's motion, which was discovered by Tycho, and which is called the annual equation, because its quantity depends, not on the place of the moon, but on the place of the sun, in the ecliptic. It is every where proportional to the inequality of the sun's motion, and is nearly a tenth part of it. The tables of Narsapour make their annual equation only of the sun's: but this is not their only mistake; for they direct the equation to be added to the moon's longitude, when it ought to be subtracted from it, and vice versa. Now, it is difficult to conceive from whence the last mentioned error has arisen; for though it is not at all extraordinary, that the astronomers, who constructed these tables, should mistake the quantity of a small equation, yet it is impossible, that the same observations, which informed them of its existence, should not have determined, whether it was to be added or subtracted. It would seem, therefore, that something accidental must have occasioned this error; but however that be, an inequality in the lunar motions, that is found in no system with which the astronomers of India can have had any communication, is at least a proof of the originality of their tables.

17. The tables, and methods, of the Brahmins of Tirvalore, are, in many respects, more singular than any that have yet been, described.[23] The solar year is divided, according to them, into twelve unequal months, each of which is the time that the sun takes to move through one sign, or 30°, of the ecliptic. Thus,

Any, or June, when the sun is in the third sign, and his motion slowest, consists of 31^{d}, 36^{h}, 38′ and *Margagy*, or December, when he is in the ninth sign, and his motion quickest, consists only of 29^{d}, 20^{h}, 53.[24] The lengths of these months, expressed in natural days, are contained in a table, which, therefore, involves in it the place of the sun's apogee, and the equation of his centre. The former seems to be 77° from the beginning of the Zodiac, and the latter about 2°, 10′, nearly as in the preceding tables. In their calculations, they also employ an astronomical day, which is different from the natural, being the time that the sun takes to move over one degree of the ecliptic; and of which days there are just 360 in a year.[25]

18. These tables go far back into antiquity. Their epoch coincides with the famous era of the Calyougham, that is, with the beginning of the year 3102 before Christ. When the Brahmins of Tirvalore would calculate the place of the sun for a given time, they begin by reducing into days the interval between that time, and the commencement of the Calyougham, multiplying the years by 365^{d}, 6^{h}, 12′, 30″; and taking away 2^{d}, 3^{h}, 32′, 30″, the astronomical epoch having begun that much later than the civil.[26] They next find, by means of certain divisions, when the year current began, or how many days have elapsed since the beginning of it, and then, by the table of the duration of months, they reduce these days into astronomical months, days, etc., which is the same with the signs, degrees and minutes of the sun's longitude from the beginning of the Zodiac. The sun's longitude, therefore, is found.

19. Somewhat in the same manner, but by a rule still more artificial and ingenious, they deduce the place of the moon, at any given time, from her place at the beginning of the Calyougham.[27] This rule is so contrived, as to include at once the motions both of the moon and of her apogee, and depends on this principle, according to the very skilful interpretation of M. Bailly, that, 1,600,894 days after the above mentioned epoch, the moon was in her apogee, and 7^{s}, 2°, 0′, 7″, distant from the beginning of the Zodiac; that after 12,372 days, the moon was again in her apogee, with her longitude increased, 9^{s}, 27°, 48′,

10″; that in 3031 days more, the moon is again in her apogee, with 11^s, 7°, 31′, 1″ more of longitude; and, lastly, that, after 248 days, she is again in her apogee, with 27°, 44′, 6″, more of longitude. By means of the three former numbers, they find, how far, at any given time, the moon is advanced in this period of 248 days, and by a table, expressing how long the moon takes to pass through each degree of her orbit, during that period, they find how far she is then advanced in the Zodiac.[28] This rule is strongly marked with all the peculiar characters of the Indian astronomy. It is remarkable for its accuracy, and still more for its ingenuity and refinement; but is not reduced withal, to its ultimate simplicity.

20. The tables of Tirvalore, however, though they differ in form very much from those formerly described, agree with them perfectly in many of their elements. They suppose the same length of the year, the same mean motions, and the same inequalities of the sun and moon, and they are adapted nearly to the same meridian.[29] But a circumstance in which they seem to

differ materially from the rest is, the antiquity of the epoch from which they take their date, the year 3102 before the Christian era. We must, therefore, enquire, whether this epoch is real or fictitious, that is, whether it has been determined by actual observation, or has been calculated from the modern epochs of the other tables. For it may naturally be supposed, that the Brahmins, having made observations in later times, or having borrowed from the astronomical knowledge of other nations, have imagined to themselves a fictitious epoch, coinciding with the celebrated era of the Calyougham, to which, through vanity or superstition, they have referred the places of the heavenly bodies, and have only calculated what they pretend that their ancestors observed.

21. In doing this, however, the Brahmins must have furnished us with means, almost infallible, of detecting their imposture. It is only for astronomy, in its most perfect state, to go back to the distance of forty-six centuries, and to ascertain the situation of the heavenly bodies at so remote a period. The modern astronomy of Europe, with all the accuracy that it derives from the telescope and the pendulum, could not venture on so difficult a task, were it not assisted by the theory of gravitation, and had not the integral calculus, after a hundred years of almost continual improvement, been able, at last, to determine the disturbances in our system, which arise from the action of the planets on one another.

Unless the corrections for these disturbances be taken into account, any system of astronomical tables, however accurate at the time of its formation, and however diligently copied from the heavens, will be found less exact for every instant, either before or after that time, and will continually diverge more and more from the truth, both for future and past ages. Indeed, this will happen, not only from the neglect of these corrections, but also from the small errors unavoidably committed, in determining the mean motions, which must accumulate with the time, and produce an effect that becomes every day more sensible, as we retire, on either side, from the instant of observation. For both these reasons, it may be established as a maxim, that, if there be given a system of astronomical tables, founded on observations of an unknown date, that date may be found, by taking the time when the tables represent the celestial motions most exactly.

Here, therefore, we have a criterion, by which we are to judge of the pretensions of the Indian astronomy to so great antiquity. It is true, that, in applying it, we must suppose our modern astronomy, if not perfectly accurate, at least so exact as to represent the celestial motions, without any sensible error, even for a period more remote than the Calyougham; and this, considering the multitude of observations on which our astronomy is founded, the great antiquity of some of those observations, and the extreme accuracy of the rest, together with the assistance derived from the theory of physical causes, may surely be assumed as a very reasonable postulatum. We begin with the examination of the mean motions.

22. The Brahmins place the beginning of their moveable Zodiac, at the time of their epoch, 54° before the vernal equinox, or in the longitude of 10^s, 6°, according to our method of reckoning. Now, M. Le Gentil brought with him a delineation of the Indian Zodiac, from which the places of the stars in it may be ascertained with tolerable exactness.[30] In particular, it appears, that Aldebaran, or the first star of Taurus, is placed in the last degree of the fourth constellation, or 53°, 20′, distant from the beginning or the Zodiac. Aldebaran was therefore 40′ before the point of the vernal equinox, according to the Indian astronomy, in the year 3102 before Christ. But the same star, by the best modern observations, was, in the year 1750, in longitude, 2^s, 6°, 17′, 47″; and had it gone forward, according to the present rate of the precession of the equinoxes, 50″ annually, it must have been, at the era of the Calyougham, 1°, 32′, before the equinox. But this result is to be corrected, in consequence of the inequality in the precession, discovered by M. De La Grange,[31] by the addition of 1°, 45′, 22″, to the longitude of Aldebaran, which gives the longitude of that star 13′ from the vernal equinox, at the time of the Calyougham, agreeing, within 53′, with the determination of the Indian astronomy.[32]

This agreement is the more remarkable, that the Brahmins, by their own rules for computing the motion of the fixed stars, could not have assigned this place to Aldebaran for the beginning of the Calyougham, had they calculated it from a modern observation. For as they make the motion of the fixed stars too great by more than 3″ annually, if they had calculated backward from 1491, they would have placed the fixed stars less advanced by 4° or 5°, at their ancient epoch, than they have actually done. This argument carries with it a great deal of force; and even were it the only one we had to produce, it would render it, in a high degree, probable, that the Indian Zodiac was as old as the Calyougham.

23. Let us next compare the places of the sun and moon, for the beginning of the Calyougham, as deduced from the Indian and the modern astronomy. And, first, of the sun, though, for a reason that will immediately appear, it is not to be considered as leading to any thing conclusive. M. Bailly, from a comparison of the tables of Tirvalore with those of Chrisnabouram, has determined the epoch of the former to answer to midnight, between the 17th and 18th[33] of February of the year 3102 before Christ, at which time the sun was just entering the moveable Zodiac, and was therefore in longitude 10^s, 6°. M. Bailly also thinks it reasonable to suppose, that this was not the mean place of the sun, as the nature of astronomical tables require, but the true place, differing from the mean, by the equation to the sun's centre at that time.[34] This, it must be confessed, is the mark of greatest unskilfulness, that we meet with in the construction of these tables. Supposing it, however, to be the case, the mean place of the sun, at the time of the epoch, comes out 10^s, 3°, 38′, 13″. Now, the mean longitude of the sun, from De La Caille's tables, for the same time, is 10^s, 1°, 5′, 57″, supposing the precession of the equinoxes to have been uniformly at the rate it is now, that is, 50″ annually. But M. De La Grange has demonstrated, that the precession was less in former ages than in the present; and his formula gives 1°, 45′, 22″, to be added, on that account, to the sun's longitude already found, which makes it 10^s, 2°, 51′, 19″, not more than 47′ from the radical place in the tables of Tirvalore. This agreement is near enough to afford a strong proof of the reality of the ancient epoch, if it were not for the difficulty that remains about considering the sun's place as the true, rather than the mean; and, for that reason, I am unwilling that any stress should be laid upon this

argument. The place of the moon is not liable to the same objection.

24. The moon's mean place, for the beginning of the Calyougham, (that is, for midnight between the 17th and 18th of February 3102, B.C. at Benares), calculated from Mayer's tables, on the supposition that her motion has always been at the same rate as at the beginning of the present century, is 10^{s}, 0°, 51′, 16″.[35] But, according to the same astronomer, the moon is subject to a small, but uniform acceleration, such, that her angular motion, in any one age, is 9″ greater than in the preceding, which, in an interval of 4801 years, must have amounted to 5°, 45′, 44″. This must be added to the preceding, to give the real mean place of the moon, at the astronomical epoch of the Calyougham, which is therefore 10^{s}, 6°, 37′. Now, the same, by the tables of Tirvalore, is 10^{s}, 6°, 0′; the difference is less than two thirds of a degree, which, for so remote a period, and considering the acceleration of the moon's motion for which no allowance could be made in an Indian calculation, is a degree of accuracy that nothing but actual observation could have produced.

25. To confirm this conclusion, M. Bailly computes the place of the moon for the same epoch, by all the tables to which the Indian astronomers can be supposed to have ever had access.[36] He begins with the tables of Ptolemy; and if, by help of them, we go back from the era of Nabonassar, to the epoch of the Calyougham, taking into account the comparative length of the Egyptian and Indian years, together with the difference of meridians between Alexandria and Tirvalore, we shall find the longitude of the sun 10°, 21′, 15″ greater, and that of the moon 11°, 52′, 7″ greater than has just been found from the Indian tables.[37] At the same time that this shows, how difficult it is to go back, even for a lesser period than that of 3000 years, in an astronomical computation, it affords a proof, altogether demonstrative, that the Indian astronomy is not derived from that of Ptolemy.

The tables of Ulugh Beig are more accurate than those of the Egyptian astronomer. They were constructed in a country not far from India, and but a few years earlier than 1491, the epoch of the tables of Chrisnabouram. Their date is July 4, at noon, 1437, at Samarcand; and yet they do not agree with the Indian tables, even at the above mentioned epoch of 1491.[38] But, for the year 3102 before Christ, their difference from them, in the place of the sun, is 1°, 30′, and in that of the moon 6°; which, though much less than the former differences, are sufficient to show, that the tables of India are not borrowed from those of Tartary.

The Arabians employed in their tables the mean motions of Ptolemy; the Persians did the same, both in the more ancient tables of Chrysococca, and the later ones of Nassireddin.[39] It is therefore certain, that the astronomy of the Brahmins is neither derived from that of the Greeks, the Arabians, the Persians or the Tartars. This appeared so clear to Cassini, though he had only examined the tables of Siam, and knew nothing of many of the great points which distinguish the Indian astronomy from that of all other nations, that he gives it as his opinion, that these tables are neither derived from the Persian astronomy of Chrysococca, nor from the Greek astronomy of Ptolemy; the places they give at their epoch to the apogee of the sun, and or the moon, and their equation for the sun's centre, being very different from both.[40]

26. But, to return to what respects the moon's acceleration; it is plain, that tables, as ancient as those of Tirvalore pretend to be, ought to make the mean motion of that planet much slower than it is at present. They do accordingly suppose, in the rule for computing the place of the moon, already described, that her motion for 4383 years, 94 days, reckoned in the moveable Zodiac from the epoch of the Calyougham, is 7^s, 2°, 0’, 7″, or 9^s, 7°, 45′, 1″, when referred to the fixed point of the vernal equinox. Now, the mean motion for the same interval, taken from the tables of Mayer, is greater than this, by 2°, 42′, 4″,[41] which, though conformable, in general, to the notion of the moon's motion having been accelerated, falls, it must be confessed, greatly short of the quantity which Mayer has assigned to that acceleration. This, however, is not true of all the tables; for the moon's motion in 4383 years, 94 days, taken from those of Chrisnabouram, is 3°, 2′, 10″ less than in the tables of

Tirvalore;[42] from which it is reasonable to conclude, with M. Bailly, that the former are, in reality, more ancient than the latter, though they do not profess to be so: and hence, also, the tables of Chrisnabouram make the moon's motion less than Mayer's, for the above mentioned interval, by 5°, 44′, 14″, which therefore is, according to them, the quantity of the acceleration.

27. Now, it is worthy of remark, that if the same be computed on Mayer's principles, that is, if we calculate how much the angular motion of the moon for 4383 years, 94 days, dated from the beginning of the Calyougham, must have been less than if her velocity had been all that time uniform, and the same as in the present century, we shall find it to be 5°, 43′, 7″, an arch which is only 1′, 7″, less than the former. The tables of Chrisnabouram, therefore, agree with those of Mayer, when corrected by the acceleration within 1′, 7″, and that for a period of more than four thousand years. From this remarkable coincidence, we may conclude, with the highest probability, that at least one set of the observations, on which those tables are founded, is not less ancient than the Calyougham; and though the possibility of their being some ages later than that epoch, is not absolutely excluded, yet it may, by strict mathematical reasoning, be inferred, that they cannot have been later than 2000 years before the Christian era.[43]

28. This last is one of the few coincidences between the astronomy of India and of Europe, which their ingenious historian has left for others to observe. Indeed, since he wrote, every argument, founded on the moon's acceleration, has become more worthy of attention, and more conclusive. For that acceleration is no longer a mere empirical equation, introduced to reconcile the ancient observations with the modern, nor a fact that can only be accounted for by hypothetical causes, such as the resistance of the ether, or the time necessary for the transmission of

gravity; it is a phenomenon, which M. De La Place has,[44] with great ability, deduced from the principle of universal gravitation, and shown to be necessarily connected with the changes in the eccentricity of the earth's orbit, discovered by M. De La Grange; so that the acceleration of the moon is indirectly produced by the action of the planets, which alternately increasing and diminishing the said eccentricity, subjects the moon to different degrees of that force by which the sun disturbs the time of her revolution round the earth. It is therefore a periodical inequality, by which the moon's motion, in the course of ages, will be as much retarded as accelerated; but its changes are so slow, that her motion has been constantly accelerated, even for a longer period than that to which the observations of India extend.

A formula for computing the quantity of this inequality, has been given by M. De La Place, which, though only an approximation, being derived from theory, is more accurate than that which Mayer deduced entirely from observation;[45] and if it be taken instead of Mayer's, which last, on account of its simplicity, I have employed in the preceding calculations, it will give a quantity somewhat different, though not such as to affect the general result. It makes the acceleration for 4383 years, dated from the beginning of the Calyougham, to be greater by 17′, 39″, than was found from Mayer's rule, and greater consequently by 16′, 32″, than was deduced from the tables of Chrisnabouram. It is plain, that this coincidence is still near enough to leave the argument, that is founded on it, in possession of all its force, and to afford a strong confirmation of the accuracy of the theory, and the authenticity of the tables.

That observations made in India, when all Europe was barbarous or uninhabited, and investigations into the most subtle effects of gravitation made in Europe, near five thousand years afterwards, should thus come in mutual support of one another, is perhaps the most striking example of the progress and vicissitude of science, which the history of mankind has yet exhibited.

29. This, however, is not the only instance of the same kind that will occur, if, from examining the radical places and mean motions in the Indian astronomy, we proceed to consider some other of its elements, such as, the length of the year, the inequality of the sun's motion, and the obliquity of the ecliptic, and compare them with the conclusions deduced, from the theory of gravity, by M. De La Grange. To that geometer, physical astronomy is indebted for one of the most beautiful of its discoveries, viz. that all the variations in our system are periodical; so that though every thing, almost without exception, be subject to change, it will, after a certain interval, return to the same state in which it is at present, and leave no room for the introduction of disorder, or of any irregularity that might constantly increase. Many of these periods, however, are of vast duration. A great number of ages, for instance, must elapse before the year be again exactly of the same length, or the sun's equation of the same magnitude as at present.[46] An astronomy, therefore, which professes to be so ancient as the Indian, ought to differ considerably from ours in many of its elements. If indeed these differences are irregular, they are the effects of chance, and must be accounted errors; but if they observe the laws, which theory informs us that the variations in our system do actually observe, they must be held as the most undoubted marks of authenticity.

We are to examine, as M. Bailly has done, which of these takes place in the case before us.[47]

30. The tables of Tirvalore, which, as we have seen, refer their date to the beginning of the Calyougham, make the siderial year to consist of 365^d, 6^h, 12′, 30″; and therefore the tropical of 365^d, 5^h, 50′, 35″, which is 1′, 46″, longer than that of De La Caille.[48] Now, the tropical year was in reality longer at that time than it is at present; for though the siderial year, or the time which the earth takes to return from one point of space to the same point again, is always of the same magnitude, yet the tropical year being affected by the precession of the equinoxes, is variable by a small quantity, which never can exceed 3′, 40″, and which is subject to slow, and unequal alternations of diminution and increase. A theorem, expressing the law and the quantity of this variation, has been investigated by M. De La Grange, in the excellent memoir already mentioned;[49] and it makes the year 3102 before Christ 40½″ longer than the year at the beginning of the present century.[50] The year in the tables of Tirvalore is therefore too great by 1′, 5½″.

31. But the determination of the year is always from a comparison of observations made at a considerable interval from one another; and, even to produce a degree of accuracy much less than what we see belongs to the tables of Tirvalore, that interval must have been of several ages. Now, says M. Bailly, if we suppose these observations to have been made in that period of 2400 years, immediately preceding the Calyougham, to which the Brahmins often refer; and if we also suppose the inequality of the precession of the equinoxes, to increase as we go back, in proportion to the square of the times, we shall find, that, at the middle of this period, or 1200 years before the beginning of the Calyougham, the length of the year was 365^d, 5^h, 50′, 41″, almost precisely as in the tables of Tirvalore. And hence it is natural to conclude, that this determination of the solar year is as ancient as the year 1200 before the Calyougham, or 4300 before the Christian era.[51]

32. In this reasoning, however, it seems impossible to acquiesce; and. M. Bailly himself does not appear to have relied on

it with much confidence.[52] We are not at liberty to suppose, that the precession of the equinoxes increases in the ratio above mentioned, or, which is the same, that the equinoctial points go back with a motion equably retarded. If, by M. De La Grange's formula, we trace back, step by step, the variation of the solar year, we shall find, that about the beginning of the Calyougham, it had nearly attained the extreme point of one of those vibrations, which many centuries are required to complete; and that the year was then longer than it has ever been since, or than it had been for many ages before. It was 40½″ longer than it is at present; but, at the year 5500 before Christ, it was only 29″ longer than at present, instead of 2′, 50″, which is the result of M. Bailly's supposition. During all the intervening period of 2400 years, the variation of the year was between these two quantities; and we cannot therefore, by any admissible supposition, reduce the error of the tables to less than 1′, 5″. The smallness of this error, though extremely favourable to the antiquity, as well as the accuracy of the Indian astronomy, is a circumstance from which a more precise conclusion can hardly be deduced.

33. The equation of the sun's centre is an element in the Indian astronomy, which has a more unequivocal appearance of belonging to an earlier period than the Calyougham. The maximum of that equation is fixed, in these tables, at 2°, 10′, 32″. It is at present, according to M. De La Caille, 1°, 55½′, that is, 15′ less than with the Brahmins. Now, M. De La Grange has shown, that the sun's equation, together with the eccentricity of the earth's orbit, on which it depends, is subject to alternate diminution and increase, and accordingly has been diminishing for many ages. In the year 3102 before our era, that equation was 2°, 6′, 28½″; less, only by 4′, than in the tables of the Brahmins. But if we suppose the Indian astronomy to be founded on observations that preceded the Calyougham, the determination of this equation will be found to be still more exact. Twelve hundred years before the commencement of that period, or about 4300 years before our era, it appears, by computing from M. De La Grange's formula, that the equation of the sun's centre was actually 2°, 8′, 16″; so that if the Indian astronomy be as old as that period, its error with respect to this equation is but of 2′.[53]

34. The obliquity of the ecliptic is another element in which the Indian astronomy and the European do not agree, but where

their difference is exactly such as the high antiquity of the former is found to require. The Brahmins make the obliquity of the ecliptic 24°. Now, M. De La Grange's formula for the variation of the obliquity,[54] gives 22′, 32″, to be added to its obliquity in 1700, that is, to 23°, 28′, 41″, in order to have that which took place in the year 3102 before our era. This gives us 23°, 51′, 13″, which is 8′, 47″, short of the determination of the Indian astronomers. But if we suppose, as in the case of the sun's equation, that the observations on which this determination is founded, were made 1200 years before the Calyougham, we shall find that the obliquity of the ecliptic was 23°, 57′, 45″, and that the error of the tables did not much exceed 2′.[55]

35. Thus, do the measures which the Brahmins assign to these three quantities, the length of the tropical year, the equation of the sun's centre, and the obliquity of the ecliptic, all agree in referring the epoch of their determination to the year 3102 before our era, or to a period still more ancient. This coincidence in three elements, altogether independent of one another, cannot be the effect of chance. The difference, with respect to each of them, between their astronomy and ours, might singly perhaps be ascribed to inaccuracy; but that three errors, which chance had introduced, should be all of such magnitudes, as to suit exactly the same hypothesis concerning their origin, is hardly to be conceived. Yet there is no other alternative, but to admit this very improbable supposition, or to acknowledge that the Indian astronomy is as ancient as one, or other of the periods above mentioned.

36. This conclusion would receive great additional confirmation, could we follow M. Bailly in his analysis of the astronomy of the planets, contained in the tables of Chrisnabouram;[56] but the length to which this paper is already extended, will allow only a few of the most remarkable particulars to be selected.

In these tables, which are for the epoch 1491, the mean motions are given with considerable accuracy, but without an appearance of being taken from Ptolemy, or any of the astronomers already mentioned. Two inequalities, called the *schigram* and the *manda*, are also distinguished in each of the planets, both superior and inferior.[57] The first of these is the same with that which we call the parallax of the earth's orbit, or the apparent inequality of a planet, which arises not from its own motion, but from that of the observer; but whether it is ascribed, in the Indian astronomy, to its true cause, or to the motion of the planet in an epicycle, is a question about which the tables give no direct information. The magnitude, however, of this equation is assigned, for each of the planets, with no small exactness, and is varied, in the different points of its orbit, by a law which approaches very near to the truth.

The other inequality coincides with that of the planet's centre, or that which arises from the eccentricity of its orbit, and it is given near the truth for all the planets, except Mercury, by which, as is no wonder, the first astronomers were, every where, greatly deceived. Of this inequality, it is supposed, just as in the cases of the sun and moon, that it is always as the sine of the planet's distance from the point of its slowest motion, or from what we call its *aphelion*, and is consequently greatest at 90° from that point.

It were to be wished that we knew the etymology of the names which are given to these inequalities, as it might explain the theory which guided the authors of the tables. The titles of our astronomical tables, the terms *aphelion*, *heliocentric* or *geocentric place*, &c. would discover the leading ideas of the Copernican system, were no other description of it preserved.

37. In the manner of applying these two inequalities, to correct the mean place of a planet, the rules of this astronomy are altogether singular. In the case of a superior planet, they do not make use of the mean anomaly, as the argument for finding out the equation *manda*, but of that anomaly, when corrected first by half the equation *schigram*, and afterwards by half the equation *manda*.[58] By the equation of the centre, obtained with this argument, the mean longitude of the planet is corrected, and its true heliocentric place consequently found, to which there is again applied the parallax of the annual orbit, that the geocentric place may be obtained. The only difficulty here, is in the method of taking out from the tables the equation to the centre.

It is evidently meant for avoiding some inaccuracy, which was apprehended from a more direct method of calculation, but of which, even after the ingenious remarks of M. Bailly, it seems impossible to give any clear and satisfactory account.

38. The manner of calculating the places of the inferior planets has a great resemblance to the former; with this difference, however, that the equation *manda*, or of the centre, is applied to correct, not the mean place of the planet, but the mean place of the sun; and to this last, when so corrected, is applied the equation *schigram* which involves the planet's elongation from the sun, and gives its geocentric place.[59] This necessarily implies, that the centre, about which the inferior planets revolve, has the same apparent mean motion with the sun: but whether it be a point really different from the sun, or the same: and, if the same, whether it be in motion or at rest, are left entirely undetermined, and we know not, whether, in the astronomy of India, we have here discovered a resemblance to the Ptolemaic, the Tychonic, or the Copernican system.

39. These tables, though their radical places are for the year 1491 of our era, have an obvious reference to the great epoch of the Calyougham. For if we calculate the places of the planets from them, for the beginning of the astronomical year, at that epoch, we find them all in conjunction with the sun in the beginning of the moveable Zodiac, their common longitude being 10^{s}, 6^{o}.[60] According to our tables, there was, at that time, a conjunction of all the planets, except Venus, with the sun; but they were, by no means, so near to one another as the Indian astronomy represents. It is true, that the exact time of a conjunction cannot be determined by direct observation: but this does not amount to an entire vindication of the tables; and there is reason to suspect, that some superstitious notions, concerning the beginning of the Calyougham, and the signs by which nature must have distinguished so great an epoch, has, in this instance at least, perverted the astronomy of the Brahmins. There are, however, some coincidences between this part of their astronomy, and the theory of gravity, which must not be forgotten.

40. The first of these respects the *aphelion* of Jupiter, which, in the tables, is supposed to have a retrograde motion of 15° in 200,000 years[61] and to have been, at the epoch of 1491, in longitude 5^{s}, 21°, 40′, 20″, from the beginning of the Zodiac. It follows, therefore, that in the year 3102 before Christ, the

longitude of Jupiter's *aphelion* was 3^s, 27°, 0′, reckoned from the equinox. Now, the same, computed from M. De La Lande's tables, is only 3^s, 16°, 48′, 58″; so that there would seem to be an error of more than 10° in the tables of the Brahmins. But, if it be considered, that Jupiter's orbit is subject to great disturbances, from the action of Saturn, which M. De La Lande does not profess to have taken into account, we will be inclined to appeal once more to M. De La Grange's formulas, before we pass sentence against the Indian astronomy.[62]

From one of these formulas, we find, that the true place of the *aphelion* of Jupiter, at the time above mentioned, was 3^s, 26°, 50′, 40″, which is but 10′, 40″, different from the tables of Chrisnabouram. The French and Indian tables are therefore both of them exact, and only differ because they are adapted to ages near five thousand years distant from one another.

41. The equation of Saturn's centre is an instance of the same kind. That equation, at present, is according to M. De La Lande, 6°, 23′, 19″; and hence, by means of one of the formulas above mentioned, M. Bailly calculates, that, 3102 years before Christ, it was 7°, 41′, 22″.[63] The tables of the Brahmins make it 7°, 39′, 44″, which is less only by 1′, 38″, than the preceding equation, though greater than that of the present century by 1°,16′, 25″.

42. M. Bailly remarks, that the equations for the other planets are not given with equal accuracy, and afford no more such instances as the former. But it is curious to observe, that new researches into the effects of gravitation, have discovered new coincidences of the same kind; and that the two great geometers, who have shared between them the glory of perfecting the *theory of disturbing forces*, have each contributed his part to establish the antiquity of the Indian astronomy. Since the publication of M. Bailly's work, two other instances of an exact agreement, between the elements of these tables, and the conclusions deduced from the theory of gravity, have been observed, and communicated to him by M. De La Place, in a letter, inserted in the *Journal des Savans*.

In seeking for the cause of the secular equations, which modern astronomers have found it necessary to apply to the mean motion of Jupiter and Saturn, M. De La Place has discovered, that there are inequalities belonging to both these planets, arising from their mutual action on one another, which have long periods, one of them no less than 877 years; so that the mean motion must appear different, if it be determined from observations made in different parts of those periods. 'Now, I find,' says he, 'by my theory, that at the Indian epoch of 3102 years before Christ, the apparent and annual mean motion of Saturn was 12°, 13′, 14″, and the Indian tables make it 12°, 13′, 13″.

'In like manner, I find, that the annual and apparent mean motion of Jupiter at that epoch was 30°, 20′, 42″, precisely as in the Indian astronomy.'[64]

43. Thus have we enumerated no less than nine astronomical elements,[65] to which the tables of India assign such values as do, by no means, belong to them in these later ages, but such as the theory of gravity proves to have belonged to them three thousand years before the Christian era. At that time, therefore, or in the ages preceding it, the observations must have been made from which these elements were deduced. For it is abundantly evident, that the Brahmins of later times, however willing they might be to adapt their tables to so remarkable an epoch as the Calyougham, could never think of doing so, by substituting, instead of quantities which they had observed, others which they had no reason to believe had ever existed. The elements in question are precisely what these astronomers must have supposed invariable, and of which, had they supposed them to change, they had no rules to go by for ascertaining the variations; since, to the discovery of these rules is required, not only all the perfection to which astronomy is, at this day, brought in Europe, but all that which the sciences of motion and of extension have likewise attained. It is no less clear, that these coincidences are not the work of accident; for it will scarcely be supposed that chance has adjusted the errors of the Indian astronomy with such singular felicity, that observers, who could not discover the true state of the heavens, at the age in which they lived, have succeeded in describing one which took place several thousand years before they were born.

44. The argument, however, which regards the originality of these tables, is, in some measure, incomplete, till we have

considered the geometrical principles which have been employed in their construction. For it is not impossible, that when seen connected by those principles, and united into general theorems, they may be found to have relations to the Greek astronomy, which did not appear, when the parts were examined singly. On this subject, therefore, I am now to offer a few observations.

45. The rules by which the phenomena of eclipses are deduced from the places of the sun and moon, have the most immediate reference to geometry; and of these rules, as found among the Brahmins of Tirvalore, M. Le Gentil has given a full account, in the *Memoir* that has been so often quoted. We have also an account of the method of calculation used at Chrisnabouram by Fr Du Champ.[66]

It is a necessary preparation, in both of these, to find the time of the sun's continuance above the horizon, at the place and the day for which the calculation of an eclipse is made, and the rule by which the Brahmins resolve this problem, is extremely simple and ingenious. At the place for which they calculate, they observe the shadow of a gnomon on the day of the equinox, at noon, when the sun, as they express it, is in the middle of the world. The height of the gnomon is divided into 720 equal parts, in which parts the length of the shadow is also measured. One third of this measure is the number of minutes by which the day, at the end of the first month after the equinox, exceeds twelve hours; four-fifths of this excess is the increase of the day during the second month; and one-third of it is the increase of the day, during the third month.[67]

46. It is plain, that this rule involves the supposition, that, when the sun's declination is given, the same ratio every where exists between the arch which measures the increase of the day at any place, and the tangent of the latitude; for that tangent is the quotient which arises from dividing the length of the shadow by the height of the gnomon. Now, this is not strictly true; for such a ratio only subsists between the chord of the arch, and the tangent above mentioned. The rule is, therefore, but an approximation to the truth, as it necessarily supposes the arch in question to be so small as to coincide nearly with its chord. This supposition holds only of places in low latitudes; and the rule which is founded on it, though it may safely be applied in countries between the tropics, in those that are more remote from the

equator, would lead into errors too considerable to escape observation.[68]

As some of the former rules, therefore, have served to fix the time, so does this, in some measure, to ascertain the place of its invention. It is the simplification of a general rule, adapted to the circumstances of the torrid zone, and suggested to the astronomers of Hindostan by their peculiar situation. It implies the knowledge of the circles of the sphere, and of spherical trigonometry, and perhaps argues a greater progress in mathematical reasoning, than a theorem that was perfectly accurate would have done. The first geometers must naturally have dreaded nothing so much as any abatement in the rigour of their demonstrations, because they would see no limits to the error and uncertainty, in which they might, by that means, be involved. It was long before the mathematicians of Greece understood how to set bounds to such errors, and to ascertain their utmost extent, whether on the side of excess or defect; in this art, they appear to have received the first lessons so late as the age of Archimedes.

47. The Brahmins having thus obtained the variations of the length of the day, at any place, or what we call the ascensional differences, apply them likewise to another purpose. As they find it necessary to know the point of the ecliptic, which is on the horizon, at the time when an eclipse happens, they have calculated a table of the right ascensions of the points of the ecliptic in time, to which they apply the ascensional differences for the place in question, in order to have the time which each of the signs takes to descend below the horizon of that place.[69] This is exactly the method, as is well known, which the most skillful astronomer, in like circumstances, would pursue. Their table of the differences of right ascension is but for a few points in the ecliptic, viz. the beginning of each sign, and is only carried to minutes of time, or tenths of a degree. It is calculated, however, so far as it goes, with perfect accuracy, and it supposes the obliquity of the ecliptic, as before, to be twenty-four degrees.

Such calculations could not be made without spherical trigonometry, or some method equivalent to it. If, indeed, we would allow the least skill possible to the authors of these tables, we may suppose, that the arches were measured on the circles of a large globe, or armillary sphere, such as we know to have been one of the first instruments of the Egyptian and Greek astronomers. But there are some of the tables where the arches are put down true to seconds, a degree of accuracy which a mechanical method can scarcely have afforded.

48. In another part of the calculation of eclipses, a direct application is made of one of the most remarkable propositions in geometry. In order to have the semiduration of a solar eclipse, they subtract from the square of the sum of the semidiameters of the sun and moon, the square of a certain line, which is a perpendicular from the centre of the sun on the path of the moon; and from the remainder, they extract the square root, which is the measure of the semiduration.[70] The same thing is practised in lunar eclipses.[71] These operations are all founded on a very distinct conception of what happens in the case of an

eclipse, and on the knowledge of this theorem, that, in a right angled triangle, the square on the hypothenuse is equal to the squares on the other two sides. It is curious to find the theorem of Pythagoras in India, where, for aught we know, it may have been discovered, and from whence that philosopher may have derived some of the solid, as well as the visionary speculations, with which he delighted to instruct or amuse his disciples.

49. We have mentioned the use that is made of the semidiameters of the sun and moon in these calculations, and the method of ascertaining them, is deserving of attention. For the sun's apparent diameter, they take four-ninths of his diurnal motion, and for the moon's diameter, one twenty-fifth of her diurnal motion. In an eclipse, they suppose the section of the shadow of the earth, at the distance of the moon, to have a diameter five times that of the moon; and in all this, there is considerable accuracy, as well as great simplicity. The apparent diameters of the sun and moon, increase and diminish with their angular velocities; and though there be a mistake in supposing, that they do so exactly in the same proportion, it is one which, without telescopes and micrometers, cannot easily be observed. The section of the earth's shadow, likewise, if the sun's apparent diameter be given, increases as the moon's increases, or as her distance from the earth diminishes, and nearly enough in the same ratio to justify the rule which is here laid down.

50. The historian of the Academy of Sciences, in giving an account of M. Le Gentil's *Memoir*, has justly observed, that the rule described in it, for finding the difference between the true and apparent conjunction, at the time of a solar eclipse, contains the calculation of the moon's parallax, but substitutes the parallax in right ascension for the parallax in longitude;[72] an error which the authors of this astronomy would probably have avoided, had they derived their knowledge from the writings of Ptolemy. From this supposed parallax in longitude, they next derived the parallax in latitude, where we may observe an application of the doctrine of similar triangles; for they suppose the first of these to be to the last in the constant ratio of 25 to 2, or nearly as the radius to the tangent of the inclination of the moon's orbit to the plane of the ecliptic. We have here, therefore, the application of another geometrical theorem, and that too proceeding on the supposition, that a small portion of the sphere, on each side of the point which the sun occupies at the middle

of the eclipse, may be held to coincide with a plane touching it in that point.

51. The result which the Brahmins thus obtain will be allowed to have great accuracy, if it be considered how simple their rules are, and how long it must be since their tables were corrected by observations. In two eclipses of the moon, calculated in India by their method, and likewise observed there by M. Le Gentil, the error, in neither case, exceeded 23′ of time, (corresponding to one of 13′ of a degree, in the place of the moon); and in the duration and magnitude of the eclipse, their calculation came still nearer to the truth.[73]

52. Since an inequality was first observed in the motions of the sun or moon, the discovery of the law which it follows, and the method of determining the quantity of it, in the different points of their orbits, has been a problem of the greatest importance; and it is curious to inquire, in what manner the astronomers of India have proceeded to resolve it. For this purpose, we must examine the tables of the *chaiaa*, or equations of the centre for the sun and moon, and of the *manda*, or equations of the centre for the planets. With respect to the first, as contained in the tables of Siam, M. Cassini observed, that the equations followed the ratio of the sines of the mean distances from the apogee; but as they were calculated only for a few points of the orbit, it could not be known with what degree of exactness this law was observed. Here, however, the tables of Chrisnabouram remove the uncertainty, as they give the equation of the centre for every degree of the mean motion, and make it nearly as the sine of the distance from the apogee.

They do so, however, only nearly; and it will be found on trial, that there is, in the numbers of the table, a small, but regular variation from this law, which is greatest when the argument is 30°, though even there it does not amount to a minute. The sun's equation, for instance, which, when greatest, or when the argument is 90°, is, by these tables, 2°, 10′, 32″, should be, when the argument is 30°, just the half of this, or 1°, 5′, 16″, did the numbers in the table follow exactly the ratio of the sines of the argument. It is, however, 1°, 6′, 3″; and this excess of 47″ cannot have arisen from any mistake about the ratio of the sine of 30° to that of 90°, which is shown to be that of 1 to 2, by a proposition in geometry[74] much too simple to have been unknown to the authors of these tables. The rule, therefore, of the equations, being proportional exactly to the sines of the argument, is not what was followed, or intended to be followed, in the calculation of them. The differences, also, between the numbers computed by that rule, and those in the tables, are perfectly regular, decreasing from the point of 30°, both ways toward the beginning and end of the quadrant, where they vanish altogether.

These observations apply also to the tables of Narsapur[75], and to the moon's equations, as well as to the sun's, with a circumstance, however, which is not easily accounted for, viz. that the differences between the numbers calculated by M. Cassini's rule, and those in the tables, are not greater in the case of the moon than of the sun, though the equation of the latter be more than double that of the former. They apply also to the tables *manda* of the planets, where the equations are greater than the ratio of the sines of their arguments requires, the excess being greatest at 30°, and amounting to some minutes in the equations of Saturn, Jupiter and Mars, in which last it is greatest of all.

53. Though, for these reasons, it is plain, that the rule of M. Cassini is not the same with that of the Brahmins, it certainly includes the greater part of it; and if the latter, whatever it may have been, were expressed in a series, according to the methods of the modern analysis, the former would be the first term of that series. We are not, however, much advanced in our inquiry in consequence of this remark; for the first terms of all the series, which can, on any hypothesis, express the relation of the

equation of the centre to the anomaly of a planet, are so far the same, that they are proportional to the sine of that anomaly; and it becomes therefore necessary to search among these hypotheses, for that by which the series of small differences, described above, may be best represented. It is needless to enter here into any detail of the reasonings by which this has been done, and by which I have found, that the argument in the table bears very nearly the same relation to the corresponding numbers, that the anomaly of the eccentric does to the equation of the centre. By the anomaly of the eccentric, however, I do not mean the angle which is known by that name in the solution of Kepler's problem, but that which serves the same purpose with it, on the supposition of a circular orbit, and an uniform angular motion about a point which is not the centre of that orbit, but which is as distant from it, on the one side, as the earth (or the place of the observer), is on the other. It is the angle, which, in such an orbit, the line drawn from the planet to the centre, makes with the line drawn from thence to the apogee; and the argument in the Indian tables coincides with this angle.

This hypothesis of a double eccentricity, is certainly not the simplest that may be formed with respect to the motion of the heavenly bodies, and is not what one would expect to meet with here; but it agrees so well with the tables, and gives the equations from the arguments so nearly, especially for the moon and the planets, that little doubt remains of its being the real hypothesis on which these tables were constructed.[76]

54. Of this, the method employed to calculate the place of any of the five planets from these tables, affords a confirmation. But, in reasoning about that method, it is necessary to put out of the question the use that is made of the parallax of the annual orbit, or of the *schigram*, in order to have the argument for finding the equation of the centre, which is evidently faulty, as it makes that equation to be affected by a quantity, (the parallax of the annual orbit), on which it has in reality no dependence. To have the rule free from error, it is to be taken, therefore, in the case when there is no parallax of the annual orbit,

that is, when the planets are in opposition or conjunction with the sun. In that case, the mean anomaly is first corrected by the subtraction or addition of half the equation that belongs to it in the table. It then becomes the true argument for finding, from that same table, the equation of the centre, which is next applied to the mean anomaly, to have the true. Now, this agrees perfectly with the conclusion above; for the mean anomaly, by the subtraction or addition of half the equation belonging to it in the table, is converted, almost precisely, into the anomaly of the eccentric, and becomes therefore the proper argument for finding out the equation, which is to change the mean anomaly into the true.[77] There can be no doubt, of consequence, that the conclusion we have come to is strictly applicable to the planets, and that the orbit of each of them, in this astronomy, is supposed to be a circle, the earth not being in its centre, but the angular velocity of the planet being uniform about a certain point, as far from that centre on the one side, as the earth is on the opposite.

55. Between the structure of the tables of the equations of the sun and moon, and the rules for using them, there is not the same consistency; for in both of them, the argument, which we have found to be the eccentric anomaly, is nevertheless treated as the mean. So far as concerns the sun, this leads to nothing irreconcilable with our supposition, because the sun's equation being small, the difference will be inconsiderable, whether the argument of that equation be treated as the eccentric or the mean anomaly.

But it is otherwise with respect to the moon, where the difference between considering the argument of the equation as the mean, or as the eccentric anomaly, is not insensible. The authority of the precepts, and of the tables, are here opposed to one another; and we can decide in favour of the latter, only because it leads to a more accurate determination of the moon's place than the former. It would indeed be an improvement on their method of calculation, which the Brahmins might make consistently with the principles of their own astronomy, to extend to the moon their rule for finding the equation of the centre for the planets. They would then avoid the palpable error of making the maximum of the moon's equation at the time when her mean anomaly is 90°, and would ascertain her place every where with greater exactness. It is probable that this is the method which they were originally directed to follow.

56. From the hypothesis which is thus found to be the basis of the Indian astronomy, one of the first conclusions which presents itself, is the existence of a remarkable affinity between the system of the Brahmins and that of Ptolemy. In the latter, the same thing was supposed for the five planets, that appears in the former to have been universally established, viz. that their orbits were circles, having the earth within them, but removed at a small distance from the centre, and that each planet described the circumference of its orbit, not with an uniform velocity, but with one that would appear uniform, if it were viewed from a point as far above the centre of the orbit, as that centre is above the earth. This point was, in the language of Ptolemy's astronomy, the centre of the *equant*.

Now, concerning this coincidence, it is the more difficult to judge, as, on the one hand, it cannot be ascribed to accident, and, on the other, it may be doubted, whether it arises necessarily out of the nature of the subject, or is a consequence of some unknown communication between the astronomers of India and of Greece.

The first hypothesis by which men endeavoured to explain the phenomena of the celestial motions, was that of an uniform motion in a circle, which had the earth for its centre. This hypothesis was, however, of no longer continuance than till instruments of tolerable exactness were directed to the heavens. It was then immediately discovered, that the earth was not the centre of this uniform motion; and the earth was therefore supposed to be placed at a certain distance from the centre of the orbit, while the planet revolved in the circumference of it with the same velocity as before. Both these steps may be accounted necessary; and in however many places of the earth, and however cut off from mutual intercourse, astronomy had begun to be cultivated, I have no doubt that these two suppositions would have succeeded one another, just as they did among the Greek astronomers.

But when more accurate observations had shown the insufficiency even of this second hypothesis, what ought naturally to be the third, may be thought not quite so obvious; and if the Greeks made choice of that which has been described above, it may seem to have been owing to certain metaphysical notions concerning the simplicity and perfection of a circular and uniform motion, which inclined them to recede from that supposition, no farther than appearances rendered absolutely necessary. The same coincidence between the ideas of metaphysics and astronomy, cannot be supposed to have taken place in other countries; and therefore, where we find this third hypothesis to have prevailed, we may conclude that it was borrowed from the Greeks.

57. Though it cannot be denied that, in this reasoning, there is some weight, yet it must be observed, that the introduction of the third hypothesis did not rest among the Greeks altogether on the coincidence above mentioned. It was suited to their progress in mathematical knowledge, and offered almost the only system, after the two former were exploded, which rendered the planetary motions the subject of geometrical reasoning, to men little versed in the methods of approximation. This was the circumstance then, which, more than any other, probably influenced them in the choice of this hypothesis, though we are not to look for it as an argument stated in their works, but may judge of the influence it had, from the frequency with which, many ages afterwards, the *ageometresia (*Transliterated from the original Greek letters: *Editor.)* of Kepler's system was objected to him by his adversaries; an objection to which that great man seemed to pay more attention than it deserved.

There is reason therefore to think, that in every country where astronomy and geometry had neither of them advanced beyond a certain point, the hypothesis of the *equant* would succeed to that of a simple eccentric orbit, and therefore cannot be admitted as a proof, that the different systems in which it makes a part, are necessarily derived from the same source. Some other circumstances attending this hypothesis, as it is found in the Indian tables, go still farther, and seem quite inconsistent with the supposition that the authors of these tables derived it from the astronomers of the West. For, *first*, it is applied by them to all the heavenly bodies, that is, to the sun and moon, as well as the planets. With Ptolemy, and with all those who founded their system on his, it extended only to the latter, insomuch that

Kepler's great reformation in astronomy, the discovery of the elliptic orbits, began from his proving, that the hypothesis of the *equant* was as necessary to be introduced for the sake of the sun's orbit, as for those of the planets, and that the eccentricity in both cases, must be bisected. It is, therefore, on a principle no way different from this of Kepler, that the tables of the sun's motion are computed in the Indian astronomy, though it must be allowed, that the method of using them is not perfectly consistent with this idea of their construction.

Secondly, the use made of the anomaly of the eccentric in these tables, as the argument of the equation of the centre, is altogether peculiar to the Indian astronomy. Ptolemy's tables of that equation for the planets, though they proceed on the same hypothesis, are arranged in a manner entirely different, and have for their argument the mean anomaly. The angle which we call the anomaly of the eccentric, and which is of so much use in the Indian tables, is not employed at all in the construction of his,[78] nor, I believe, in those of any other astronomer till the time of Kepler; and even by Kepler it was not made the argument of the equation to the centre. The method, explained above, of converting the mean anomaly into that of the eccentric, and consequently into the argument of the equation, is another peculiarity, and though simple and ingenious, has not the accuracy suited to the genius of the Greek astronomy, which never admitted even of the best approximation, when a rigorous solution could be found; and, on the whole, if the resemblance of these two systems, even with all the exceptions that have been stated, must still be ascribed to some communication between the authors of them, that communication is more likely to have gone from India to Greece, than in the opposite direction. It may perhaps be thought to favour this last opinion, that Ptolemy has no where demonstrated the necessity of assigning a double eccentricity to the orbits of the planets, and has left room to suspect, that authority, more than argument, has influenced this part of his system.

58. In tables of the planets, we remarked another equation, (*schigram*) answering to the parallax of the earth's orbit, or the difference between the heliocentric and the geocentric place of the planet. This parallax, if we conceive a triangle to be formed by lines drawn from the sun to the earth and to the planet, and also from the planet to the earth, is the angle of that triangle,

subtended by the line drawn from the sun to the earth. And so, accordingly, it is computed in these tables; for if we resolve such a triangle as is here described, we will find the angle, subtended by the earth's distance from the sun, coincide very nearly with the *schigram*.

The argument of this equation is the difference between the mean longitude of the sun and of the planet. The orbits are supposed circular; but whether the inequality in question was understood to arise from the motion of the earth, or from the motion of the planet in an epicycle, the centre of which revolves in a circle, is left undetermined, as both hypotheses may be so adjusted as to give the same result with respect to this inequality. The proportional distances of the planets from the earth or the sun, may be deduced from the tables of these equations, and are not far from the truth.

59. The preceding calculations must have required the assistance of many subsidiary tables, of which no trace has yet been found in India. Besides many other geometrical propositions, some of them also involve the ratio which the diameter of a circle was supposed to bear to its circumference, but which we would find it impossible to discover from them exactly, on account of the small quantities that may have been neglected in their calculations. Fortunately, we can arrive at this knowledge, which is very material when the progress of geometry is to be estimated, from a passage in the *Ayeen Akbery*, where we are told, that the Hindoos suppose the diameter of a circle to be to its circumference as 1250 to 3927,[79] and where the author, who knew that this was more accurate than the proportion of Archimedes, (7 to 22), and believed it to be perfectly exact, expresses his astonishment, that among so simple a people, there should be found a truth, which, among the wisest and most learned nations, had been sought for in vain.

The proportion of 1250 to 3927 is indeed a near approach to the quadrature of the circle; it differs little from that of Metius, 113 to 355, and is the same with one equally remarkable, that of I to 3.1416. When found in the simplest and most elementary way, it requires a polygon of 768 sides to be inscribed in a circle; an operation which cannot be arithmetically performed without the knowledge of some very curious properties of that curve, and, at least, nine extractions of the square root, each as far as ten places of decimals. All this must have been accomplished in

India; for it is to be observed, that the above mentioned proportion cannot have been received from the mathematicians of the West. The Greeks left nothing on this subject more accurate than the theorem of Archimedes; and the Arabian mathematicians, seem not to have attempted any nearer approximation. The geometry of modern Europe can much less be regarded as the source of this knowledge. Metius and Vieta were the first, who, in the quadrature of the circle, surpassed the accuracy of Archimedes; and they flourished at the very time when the Institutes of Akbar were collected in India.

60. On the grounds which have now been explained, the following general conclusions appear to be established.

I. The observations on which the astronomy of India is founded, were made more than three thousand years before the Christian era; and, in particular, the places of the sun and the moon, at the beginning of the Calyougham, were determined by actual observation.

This follows from the exact agreement of the radical places in the tables of Tirvalore, with those deduced for the same epoch from the tables of De La Caille and Mayer, and especially in the case of the moon, when regard is had to her acceleration. It follows, too, from the position of the fixed stars in respect of the equinox, as represented in the Indian Zodiac; from the length of the solar year; and, lastly, from the position and form of the orbits of Jupiter and Saturn, as well as their mean motions; in all of which, the tables of the Brahmins, compared with ours, give the quantity of the change that has taken place, just equal to that which the action of the planets on one another may be shown to have produced, in the space of forty-eight centuries, reckoned back from the beginning of the present.

Two other of the elements of this astronomy, the equation of the sun's centre, and the obliquity of the ecliptic, when compared with those of the present time, seem to point to a period still more remote, and to fix the origin of this astronomy 1000 or 1200 years earlier, that is, 4300 years before the Christian era; and the time necessary to have brought the arts of calculating and observing to such perfection as they must have attained at the beginning of the Calyougham, comes in support of the same conclusion.

Of such high antiquity, therefore, must we suppose the origin of this astronomy; unless we can believe, that all the coincidences which have been enumerated, are but the effects of chance; or what indeed were still more wonderful, that, some ages ago, there had arisen a Newton among the Brahmins, to discover that universal principle which connects, not only the most distant regions of space, but the most remote periods of duration; and a De La Grange, to trace, through the immensity of both, its most subtle and complicated operations.

II. Though the astronomy which is now in the hands of the Brahmins, is so ancient in its origin, yet it contains many rules and tables that are of later construction.

The first operation for computing the moon's place from the tables of Tirvalore, requires that 1,600,984 days should be subtracted from the time that has elapsed since the beginning of the Calyougham, which brings down the date of the rule to the year 1282 of our era. At this time, too, the place of the moon, and of her apogee, are determined with so much exactness, that it must have been done by observation, either at the instant referred to, or a few days before or after it. At this time, therefore, it is certain, that astronomical observations were made in India, and that the Brahmins were not, as they are now, without any knowledge of the principles on which their rules are founded. When that knowledge was lost, will not perhaps be easily ascertained; but there are, I think, no circumstances in the tables from which we can certainly infer the existence of it at a later period than what has just been mentioned; for though there are more modern epochs to be found in them, they are such as may have been derived from the most ancient of all, by help of the mean motions in the tables of Chrisnabouram,[80] without any other skill than is required to an ordinary calculation. Of these epochs, beside what have been occasionally mentioned in the course of our remarks, there is one (involved in the tables of Narsapur) as late as the year 1656, and another as early as the year 78 of our era, which marks the death of Salivaganam, one of their princes, in whose reign a reform is said to have taken place in the methods of their astronomy. There is no reference to any intermediate date, from that time to the beginning of the Calyougham.

The parts of this astronomy, therefore, are not all of the same antiquity; nor can we judge, merely from the epoch to which the tables refer, of the age, to which they were originally adapted. We have seen, that the tables of Chrisnabouram, though they profess to be no older than the year 1491 of our era, are, in reality, more ancient than the tables of Tirvalore, which are dated from the Calyougham, or at least have undergone fewer alterations. This we concluded from the slow motion given to the moon, in the former of these tables, which agreed, with such wonderful precision, with the secular equation applied to that planet by Mayer, and explained by M. De La Place.

But it appears, that neither the tables of Tirvalore or Chrisnabouram, nor any with which we are yet acquainted, are the most ancient to be found in India. The Brahmins constantly refer to an astronomy at Benares, which they emphatically style *the ancient*,[81] and which they say is not now understood by them, though they believe it to be much more accurate than that by which they calculate. That it is more accurate, is improbable; that it may be more ancient, no one who has duly attended to the foregoing facts and reasonings, will think impossible; and every one, I believe, will acknowledge, that no greater service could be rendered to the learned world, than to rescue this precious fragment from obscurity. If that is ever to be expected, it is when the zeal for knowledge has formed a literary society among our countrymen in Bengal, and while that society is directed by the learning and abilities of Sir William Jones. Indeed, the farther discoveries which may be made with respect to this science, do not interest merely the astronomer and the mathematician, but every one who delights to mark the progress of mankind, or is curious to look back on the ancient inhabitants of the globe. It is through the medium of astronomy alone that a few rays from those distant objects can be conveyed in safety to the eye of a modern observer, so as to afford him a light, which, though it be scanty, is pure and unbroken, and free from the false colourings of vanity and superstition.

III. The basis of the four systems of astronomical tables which we have examined, is evidently the same.

Though these tables are scattered over an extensive country, they seem to have been all originally adapted, either to the same meridian, or to meridians at no great distance, which traverse what we may call the classical ground of India, marked by the ruins of Canoge, Palibothra and Benares. They contain rules that have originated between the tropics; whatever be their epoch, they are all, by their mean motions, connected with that of the Calyougham; and they have besides one uniform character which it is perhaps not easy to describe. Great ingenuity has been exerted to simplify their rules; yet, in no instance almost, are they reduced to the utmost simplicity; and when it happens that the operations to which they lead are extremely obvious, these are often involved in an artificial obscurity. A Brahmin frequently multiplies by a greater number than is necessary, where he seems to gain nothing but the trouble of dividing by one that is greater in the same proportion; and he calculates the era of Salivaganam with the formality of as many distinct operations as if he were going to determine the moon's motion since the beginning of the Calyougham. The same spirit of exclusion, the same fear of communicating his knowledge, seems to direct the calculus which pervades the religion of the Brahmin; and in neither of them, is he willing to receive or to impart instruction. With all these circumstances of resemblance, the methods of this astronomy are as much diversified as we can suppose the same system to be, by passing through the hands of a succession of ingenious men, fertile in resources, and acquainted with the variety and extent of the science which they cultivated. A system of knowledge, which is thus assimilated to the genius of the people, that is diffused so widely among them, and diversified so much, has a right to be regarded, either as a native, or a very ancient inhabitant of the country where it is found.

IV. The construction of these tables implies a great knowledge of geometry, arithmetic, and even of the theoretical part of astronomy.

In proof of this, it is unnecessary to recapitulate the remarks that have been already made. It may be proper, however, to add, that the method of calculating eclipses, to which these tables are subservient, is, in no respect, an empirical one, founded on the mere observation of the intervals at which eclipses return, one after another, in the same order. It is indeed remarkable, that we find no trace here of the period of 6585 days and 8 hours, or 223 lunations, the *Saros* of the Chaldean astronomers, which they employed for the prediction of eclipses, and which (observed with more or less accuracy) the first astronomers every where must have employed, before they were able to analyse eclipses, and to find out the laws of every cause contributing to them. That empirical method, if it once existed in India, is now forgotten, and has long since given place to the more scientific and accurate one, which offers a complete analysis of the phenomena, and calculates, one by one, the motions of the sun, of the moon, and of the node.

But what, without doubt, is to be accounted the greatest refinement in this system, is the hypothesis employed in calculating the equations of the centre for the sun, moon and planets, that, viz. of a circular orbit having a double eccentricity, or having its centre in the middle, between the earth and the point about which the angular motion is uniform.[82] If to this we add the great extent of geometrical knowledge requisite to combine this, and the other principles of their astronomy together and to deduce from them the just conclusions; the possession of a calculus equivalent to trigonometry; and, lastly, their approximation to the quadrature of the circle, we shall be astonished at the magnitude of that body of science, which must have enlightened the inhabitants of India in some remote age, and which, whatever it may have communicated to the western nations, appears to have received nothing from them.

Such are the conclusions that seem to me to follow, with the highest probability, from the facts which have been stated. They are, without doubt, extraordinary; and have no other claim to our belief, except that, as I think has been fully proved, their being false were much more wonderful than their being true. There are but few things, however, of which the contrary is impossible. It must be remembered, that the whole evidence on this subject is not yet before the public, and that the repositories of Benares may contain what is to confirm or to invalidate these observations.

Notes

1. *Mem. Acad. Scien.*, tom.8, p.281 & c.
2. *Traite de L'Astronomie Indienne et Orientale*, par M. Bailly. Paris, 1787.
3. *Mem. sur I'Astronomie des Indiens*, par M.Le GENTIL, *Hist. Acad. Scien.*, 1772, II, p.207. The phrase which we here translate *constellations*, signifies *the places of the moon in the twelve signs*.
4. *Mem. Acad. Scien.*, 1772 II, p.189
5. *Ibid.*209.
6. *Mem. Acad. Scien.* 1772 II, p.200. The Zodiac they call *sodi-mandalam* or the circle of stars.
7. *Ibid.* 194. *Ast. Ind.*, p.43 & c.
8. *Mem.Acad.Scien.* tom.8, p.312. *Ast.Ind.*, p.11, §14.
9. *Ast.Ind.*, p.7.§ 6.
10. *Mem. Acad. Scien.* tom.8, p.328.
11. *Ast. Ind.*, p.124. The tables of Tirvalore make the year 6″ less.
12. The equation of the sun, or what they call the *chaiaa*, is calculated in the Siamese tables only for every 15° of the *matteiomme*, or mean anomaly. Cassini, *ubisupra*, p.299.
13. *Ast. Ind.*, p.9.
14. The error, however, with respect to the apogee, is less than it appears to be; for the motion of the Indian Zodiac, being nearly 4′ swifter than the stars, is but 6″ slower than the apogee. The velocity of the Indian Zodiac is indeed neither the same with that of the stars, nor of the sun's apogee, but nearly a mean between them.
15. The Indian period is more exact than that of our golden number, by 35′. *Ast. Ind.*, p.5. The Indians regulate their festivals by this period. *Ibid. Disc. Prelim.*, p.viii.
16. *Ast. Ind.*, pp.11 & 20.
17. *Ast. Ind.*, p.13. Cassini *Mem. Acad. Scien.* tom.8, p.304.
18. *Mem. Acad. Scien.* tom.8, pp.302 & 309.
19. *Ast. Ind.*, p.12. It brings us to a meridian 82°, 34′, east of Greenwich. Benares is 83°, 11′, east of the same, by Rennel's map.

20. These tables are published by M. Bailly, *Ast. Ind.*, p.335 & c. See also p.31, & c.

21. *Ast. Ind.*, p.49 & c.

22. They were explained, or rather decyphered by M. Le Gentil in the Memoirs of the Academy of Sciences for 1784, p.482 & c.; for they were not understood by the missionary who sent them to Europe, nor probably by the Brahmins who instructed him. M. Le Gentil thinks that they have the appearance of being copied from inscriptions on stone. The minutes and seconds are ranged in rows under one another, not in vertical columns, and without any title to point out their meaning, or their connection. These tables are published, *Mem. Acad. Scien.* Ibid p.492, and *Ast. Ind.*, p.414.

23. Tirvalore is a small town on the Coromandel coast, about 12 G. miles west of Negapatnam, in Lat. 10°, 44′, and east Long. from Greenwich, 79°, 42′, by Rennel's map. From the observations of the Brahmins,

M. Le Gentil makes its Lat. to be 10°, 42′, 13″. (*Mem. Acad. Scien.* II, p.184) The meridian of Tirvalore nearly touches the west side of Ceylon, and therefore may be supposed to coincide with the first meridian, as laid down by Father Du Champ. There is no reduction of longitude employed in the methods of Tirvalore.

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24. These are Indian hours, & c.

25. *Mem. Acad. Scien.* II, p.187; *Ast. Ind.*, p.76 & c.

26. The Indian hours are here reduced to European.27. *Mem. Acad. Scien*, Ibid. p.229. *Ast. Ind.*, p.84.

27.*Mem. Acad. des Scien,* ibid.p.229. *Asst.Ind.* p.84.

28. M. Le Gentil has given this table, *Mem. Acad. Scien.*, Ibid. p.261.

29. The accuracy of the geography of the Hindoos, is in no proportion to that of their astronomy, and, therefore, it is impossible that the identity of the meridians of their tables can be fully established. All that can be said, with certainty, is, that the difference between the meridians of the tables of Tirvalore and Siam is, at most, but inconsiderable, and may be only apparent, arising from an error in computing the difference of longitude between these places. The tables of Tirvalore are for Long.

79°, 42′; those of Siam for 82°, 34′; the difference is 2°, 52′, not more than may be ascribed to an error purely geographical.

As to the tables of Chrisnabouram, they contain a reduction, by which it appears, that the place where they are now used is 45′ of a degree east of the meridian for which they were originally constructed. This makes the latter meridian agree tolerably with that of Cape Comorin, which is in Long. 77°, 32′, 30″, and about half a degree west of Chrisnabouram. But this conclusion is uncertain; because, as M. Bailly has remarked, the tables sent from Chrisnabouram, and understood by Fr Du Champ to belong to that place, are not adapted to the latitude of it, but to one considerably greater, as appears from their rule for ascertaining the length of the day.(*Ast. Ind.*, p.33).

The characters, too, by which the Brahmins distinguish their first meridian, are not perfectly consistent with one another. Sometimes it is described as bisecting Ceylon; and at other times, as touching it on the west side, or even as being as far west as Cape Comorin. Lanka, which is said to be a point in it, is understood, by Fr Du Champ, to be Ceylon. M. Bailly thinks that it is the lake Lanka, the source of the Gogra, placed by M. Rennel, as well as the middle of Ceylon, in Long. 80°, 42′; but, from a Hindoo map, in the *Ayeen Akbery*, vol.iii. p.25, Lanka appears to be an island, which marks the intersection of the first meridian of the map, nearly that of Cape Comorin, with the equator; and is probably one of the Maldivy islands. See also a note in the *Ayeen Akbery*, Ibid. p.36.

30. *Mem. Acad. Scien.* 1772 II, p.214. *Ast. Ind.*, p.129.

31. *Mem. Acad. Berlin* 1782, p.387. *Ast. Ind.*, p.144.

32. *Ast. Ind.* p.130.

33. *Ast. Ind.*, p.110. The Brahmins, however, actually suppose the epoch to be 6 hours later, or at sunrise, on the same day. Their mistake is discovered, as has been said, by comparing the radical places in the different tables with one another.

34. *Ast. Ind.*, p.83.

35. *Ast. Ind.*, p.142 & c. The first meridian is supposed to pass through Benares; but even if it be supposed 3° farther west, the difference, which is here 37′, will be only increased to 42′.

36. *Ast. Ind.*, p.114.

37. *Ibid.* p.115.

38. *Ibid.* p.117.

39. *Ibid.* p.118.

40. *Mem. Acad. Scien.* tom.8, p.286.

41. *Ast. Ind.*, p.145.

42. *Ibid.* p.126.

43. The reasoning here referred to is the following: As the mean motions, in all astronomical tables, are determined by the comparison of (*contd...*) observations made at a great distance of time from one another; if x be the number of centuries between the beginning of the present, and the date of the more ancient observations, from which the moon's mean motion in the tables of Chrisnabouram is deduced; and if y denote the same for the more modern observations: then the quantity by which the moon's motion, during the interval $x - y$, falls short of Mayer's, for the same interval, is . $(x^2 - y^2)9''$

If, therefore, m be the motion of the moon for a century in the last mentioned tables, $m(x-y) - 9''(x^2 - y^2)$ will be the mean motion for the interval $x - y$ in the tables of Chrisnabouram. If, then, a be any other interval, as that of 43.83 centuries, the mean motion assigned to it, in these last tables, by the rule of proportion, will be

$$\frac{ma(x-y)-9''a(x^2-y^2)}{x-y}=ma-9a(x+y)$$

Let this motion, actually taken from the tables be $= na$,

then $ma - na = 9a(x+y)$ or $x+y=\frac{m-n}{g}=52.19$ in the present case

It is certain, therefore, that whatever supposition be made with respect to the interval between x and y, their sum must always be the same, and must amount to 5219 years. But that, that interval may be long enough to give the mean motions with exactness, it can scarcely be supposed less than 2000 years; and, in that case, $x = 3609$ years, which therefore is its least value. But if 3609 be reckoned back from 1700, it goes up to 1909 years before Christ, nearly, as has been said.

It must be remembered, that what is here investigated is the limit, or the most modern date possible to be assigned to the observations in question. The supposition that $x - y = a$, is the most probable of all, and it gives $x = 4801$, which corresponds to the beginning of the Calyougham.

44. *Mem. Acad. Scien.* 1786, p.235, & c.

45. *Mem. Acad. Scien.* 1786, p.260.

46. *Mem. Acad. Berlin*, 1782, p.170, & c.

47. *Ast. Ind. p.160*, & c.

48. Supra, §18 and 10.

49. *Mem. Acad. Berlin*, 1782. p.289.

50. *Ast. Ind.*, p.160.

51. *Ibid.* p.161.

52. He says, '*Sans doute il ne peut resulter de ce calcul qu'un appercu.*'

53. *Ast. Ind.*, p.163.

54. *Mem. Acad. Berlin* 1782, p.287.

55. *Ast. Ind.*, p.165.

56. *Ast. Ind.*, p.173, & c.

57. *Ibid.* p.177.

58. *Ast. Ind.*, p.194.

59. *Ibid.* p.199 & c.

60. *Ast. Ind.*, p.181.

61. *Ibid.* p.184. §13.62. *Mem. Acad. Berlin* 1782, p.246. *Ast. Ind.*, p.186.

62. *Mem. Acad. Berlin*, 1782. p.246. *Asst. Ind.* p.186.

63. *Ast.Ind.*, p.188.

64. *Esprit des Journeaux* Nov. 1787, p.80.

65. The inequality of the precession of the equinoxes, (§22); the acceleration of the moon; the length of the solar year; the equation of the sun's centre; the obliquity of the ecliptic; the place of Jupiter's *aphelion*; the equation of Saturn's centre; and the inequalities in the mean motion of both these planets.

66. *Ast. Ind.*, p.355 & c.

67. *Mem. Acad. Scien.* II, p.175.

68. To judge of the accuracy of this approximation, suppose O to be the obliquity of the ecliptic, and x the excess of the semidiurnal arch, on the longest day, above an arch of 90°, then

$$\sin.\ x = \tan.\ O \times \tan.\ \text{lat}.$$

But if G be the height of a gnomon, and S the length of its shadow on the equinoctial day,

$$\frac{S}{G} = \tan.\ \text{lat and } \sin.\ x = \tan.\ O \times \frac{S}{G}.$$ Therefore,

$$x = \tan.O \times \frac{S}{G} + \frac{\tan.O^3 \times S^3}{6G^3} + \frac{\tan.O^5 \times S^5}{24G^5} + \&c.$$

or in minutes of time, reckoned after the Indian manner,

$$x = 572.957(\tan.O \times \frac{S}{G} + \tan.O^3 \times \frac{S^3}{6G^3} + \&c.)$$

If , then , and the first term of this formula gives

$$x = 572.957 \times \frac{.4452S}{G} = \frac{255S}{G}$$

which is the same with the rule of the Brahmins. For that rule, reduced into a formula, is

$$2x = \frac{720S}{G}(\frac{1}{3} + \frac{4}{15} + \frac{1}{9}) = \frac{512S}{G}, \text{ or } x = \frac{256S}{G}.$$

They have therefore computed the coefficient of $\frac{S}{G}$ with sufficient accuracy; the error produced by the omission of the rest of the terms of the series will not exceed 1′, even at the tropics, but, beyond them, it increases fast, and, in the latitude of 45°, would amount to 8′.

69. *Mem. Acad. Scien.* 1772 II, p.205.

70. *Mem. Acad. Scien.* 1772 II, p.259.

71. *Ibid.* 241.

72. *Hist. Acad.* II, p.109. Ibid. Mem. 253-256.

73. In the language, however, of their rules, we may trace some marks of a fabulous and ignorant age, from which indeed even the astronomy of Europe is not altogether free. The place of the moon's ascending node, is with them *the place of the Dragon* or *the Serpent*; the moon's distance from the node, is literally translated by M. Le Gentil, *la lune offensée du dragon*. Whether it be that we have borrowed these absurdities from India, along with astrology, or if the popular theory of eclipses has, at first, been every where the same, the moon's node is also known with us by the name of the *cauda draconis*. In general, however, the signification of the terms in these rules, so far as we know it, is more rational. In one of them we may remark considerable refinement; *ayanangsam*, which is the name for the reduction made on the sun's longitude, on account of the precession of the equinoxes, is compounded from *ayanam*, a *course*, and *angsam*, an *atom*. *Mem. Acad. Scien.* II. p.251. The equinox is almost the only point not distinguished by a visible object, of which the *course* or motion is computed in this astronomy.

74. *Euc. Lib.* IV, Prop.15.

75. See these tables, *Ast. Ind.*, p.414.

76. The formula deduced from this hypothesis, for calculating the equation of the centre from the anomaly of the eccentric, is the following. Let x be the equation of the centre, ϕ the anomaly of the eccentric, e the eccentricity of the orbit, or the tangent of half the greatest equation;

then $$x = 2e\ \sin.\phi + \frac{2e^3 \sin.3\phi}{3} + \frac{2e^5 \sin.5\phi}{5} + \&c.$$

77. This method of calculation is so nearly exact, that even in the orbit of Mars, the equation calculated from the mean anomaly, rigorously on the principle of his angular motion being uniform, about a point distant from the centre, as described above, will rarely differ a minute from that which is taken out from the Indian tables by this rule. It was remarked, (§37) that it is not easy to explain the rules for finding the argument of the equation of the centre, for the planets. What is said here explains fully one part of that rule, viz. the correction made by half the equation *manda*; the principle on which the other part proceeds, viz. the correction by half the equation *schigram*, is still uncertain.

78. *Almagest. lib.* XI, cap.9 & 10.

79. *Ayeen Akbery*, Vol.III. p.32.

80. *Ast. Ind.* p.307.

81. *Ast. Ind.* p.309, M. Le Gentil, *Mem. Acad. Scien.* 1772. p.II. p.221.

82. It should have been remarked before, that M. Bailly has taken notice of the analogy between the Indian method of calculating the places of the planets, and Ptolemy's hypothesis of the *equant*, though on different principles from those that have been followed here, and such as do not lead to the same conclusion. In treating of the question, whether the sun or earth has been supposed the centre of the planetary motions by the authors of this astronomy, he says, '*Ils semblent avoir reconnu que les deux inegalites (l'equation du centre et la parallaxe de l'orbe annuel) etoient rues de deux centres differens; et dans l'impossibilite ou ils etoient de determiner et le lieu et la distance des deux centres, ils ont imagine de rapporter les deux inegalites aun point qui tint le milieu, c'est-a-dire, a un point egalement eloigne du soliel, et de la terre. Ce nouveau centre resemble assez au centre de I' equant de Ptolemee.' (Ast. Ind. Disc. Prel.* p.69.) The fictitious centre, which M. Bailly compares with the *equant* of Ptolemy, is therefore a point which bisects the distance between the sun and earth, and which, in some respects, is quite different from that *equant*; the fictitious centre, which, in the preceding remarks, is compared with the *equant* of Ptolemy, is a point of which the distance from the earth is bisected by the centre of the orbit, precisely as in the case of that *equant*. M. Bailly draws his conclusion from the use made of half the equation of *schigram*, as well as half the equation *manda*, in order to find the argument of this last equation. The conclusion here is established, by abstracting altogether from the former, and considering the cases of oppositions and conjunctions, when the latter equation only takes place. If, however, the hypothesis of the *equant* shall be found of importance in the explanation of the Indian astronomy, it must be allowed that it was first suggested by M. Bailly, though in a sense very different from what it is understood in here, and from what it was understood in by Ptolemy.

For what further relates to the parts of the astronomy of Chaldea and of Greece, which may be supposed borrowed from that of India, I must refer to the 10th Chap. of the *Astronomie Indienne*, where that subject is treated with great learning and ingenuity. After all the silence of the ancients with respect of Indian astronomy, is not easily accounted for. The first mention that is made of it, is by the Arabian writers; and M. Baille quotes a very singular passage, where Massoudi, and author of the 12th century, says, that Brama composed a book entitled, *Sind-Hind*, that is, *Of the Age of Ages*, from which was composed the book *Maghisti*, and from thence the *Almagest* of Ptolemy. (*Ast. Ind. Disc. Prel.* p.175.)

The fabulous air of this passage is, in some measure, removed, by comparing it with one from Abulfaragius, who says, that, under the celebrated Al Maimon, the 7th Khalif of Babylon, (about the year 813 of our era) the astronomer Habash composed three sets of astronomical tables, one of which was *ad regulas Sind Hind*; that is, as Mr Costard explains it, according to the rules of some Indian treatise of astronomy. (*Asiatic Miscel*...Vol.I. p.34.) The *Sind-Hind* is therefore the name of an astronomical book that existed in India in the time of Habash, and the same, no doubt, which Massoudi says was ascribed to Brama.

III

HINTS CONCERNING THE OBSERVATORY AT BENARES

(By Reuben Burrow (circa 1783). A few names and words are not clearly decipherable in the original. These have been marked with an asterisk. The most likely reading of them is given in this printed version—*Editor.)*

Observations of the ancient monuments have the same relation to history and the arts, that experiments have to natural philosophy; without the last, philosophy is little better than a dream, and exclusive of the former, conjecture is vague and indeterminate.

To establish an intercourse with the learned of different nations, and to unite their collective force in surmounting the difficulties of art, and extending the boundaries of knowledge, were the primary motives of the first institutors of the royal societies of London and Paris; they knew that science would become the easier as its generality increased, and were conscious of the vast advantages that would arise from the auxiliary support of antiquity in the investigation of truth: Convinced of the veracity of this principle, the antiquarians of Europe were at immense expences in collecting medals, and taking the draughts and dimensions of the Greek, Roman, Palmyrean and Egyptian antiquities; and though much greater advantages may be expected from those collections hereafter, when more generally known, yet even the improvements derived from them already in the single article of architecture have more than compensated the expence, and may fully be considered as a national advantage, whether we respect their utility, duration, conveniency or elegance.

Notwithstanding the prejudices of the Europeans of last century in favour of their own abilities, some of the first members of the royal society were sufficiently enlightened to consider the East Indies and China & c., as new worlds of science that yet remained undiscovered. They wrote out lists of queries; furnished new heads of enquiry, and seemed extremely desirous of possessing the literary treasures of these unexplored regions of knowledge of which they had formed such sanguine expectations. They failed in these endeavours; it is true, by employing improper means, but the attempt will ever be a monument of the wisdom and public spirit of the employees; and had they not too hastily concluded that to be lost, which nothing but the prejudices of ignorance and obstinacy, had prevented being found; we might at this time [be] in possession of the most finished productions of Asia, as well as of Europe; the sciences might, in consequence, have been carried to a much higher degree of perfection with us than they are at present; and the elegance and superiority of the Asiatic models might have prevented that neglect and depravity of Geometry, and that inundation of Algebraic barbarism which has ever since the time of Descartes, both vitiated taste, and overrun the publications, of most of the philosophical societies in Europe.

But notwithstanding that the ruins and repositories of Greece and Rome have been ransacked and scrutinised for antiquities, these former prejudices are still in force, and the East Indies are almost entirely neglected; for though the country teems with curiosities of almost every kind, yet excepting the late translation of the Code of Gentoo laws, Europe has received less information from her sons in these matters, than if she had dispatched none to the East but Huns and barbarians; and yet there is a reason to believe that was the 'Parent of the Sciences' (notwithstanding that epithet is usually applied to Egypt): for the Chinese on the one side, and the Babylonians on the other, we know had astronomical observations, and yet Egypt with all her boasted antiquity had none.

In all the Grecian, Roman and Egyptian remains there does not appear to be the least vestige of an observatory: The pyramids are said indeed to have been placed north and south for some astronomical purpose, and we are told that Delhazelles* examined the largest of them about a century ago and found it so; but this I very much doubt; for if he examined one, it must have been great want of curiosity not to examine more; and even if he was capable of making the examination, (which is dubious) neither France nor England could at that time have furnished him with an instrument sufficiently exact; besides, it is not certain, nor even very probable that the builders of the pyramid took any uncommon pains to place the building in the plane of the meridian that seems only designed for a funeral monument: And yet from this single and doubtful observation have philosophers concluded that the earth has not altered its axis! It was not indeed supposed till very lately that there was any practical mode of determining the matter; but fortunately for astronomy there is a large Quadrant existing at Benares which from the intent of its construction must necessarily have been placed in the plane of the meridian when the observatory was erected; and as this Quadrant is an immoveable structure of solid massy stones, and consequently not liable to vary its azimuth, or bend like European quadrants the transits and altitudes of a number of stars may be taken with it, by a proper contrivance; and its position with respect to the meridian and equator & c. found out with the greatest exactness; from whence many useful conclusions may be drawn, and this very curious and difficult affair perhaps determined.

It is well known that the problems of finding the precession of the equinoxes, and the mutation of the earth's axis, have been considered by some of the most learned mathematicians, and yet they are not agreed concerning it: Some great authors as Newton, Simpson, Walmsley and Sylvain Bailly, supposed the action of the sun and moon to bring the equator out of its place, and to make it revolve round the old axis in a different position; while others as d'Alembert, Euler, La Grange and Titius, suppose the result to be a new equator and a new axis. This last seems indeed to be partly the case, for we cannot otherwise account for equatorial productions being found in Russia and Siberia; nor how those of the frozen zone should be found in the torrid: The matter however is still very doubtful, and requires the aid of observations; for in my opinion even those that have treated the subject best, have omitted some parts that are very essential; for some of them have made a wrong estimation of the quantity of the solar force and all of them have assumed the rigidity of the protuberant parts of the earth's equator, in their calculations; which is evidently contrary to fact; because we know that near 5/6th of the whole equator is covered with water; and there are not even signs of shallows any where in it, to speak of, except in the short distance between Madagascar and Sumatra: This must make so great a difference in the result that it scarcely seems possible to determine the matter alone by theory: The fact however is certain, that the best mathematicians differ greatly in their conclusions; but if the earth acquires a new axis the meridians will consequently be changed; and if the Quadrant at Benares was placed in the plane of the meridian when the building was erected, it cannot be in the plane of the meridian now; and therefore if the quantity of its deviation from that plane, be carefully and accurately determined it may answer many useful purposes in astronomy, and likewise be serviceable when the theory is perfect to point out the time when the observatory was built, exclusive of its use in the mutation and precession.

It is also probable that some useful information may be had from the Observatory at Benares, respecting the obliquity of the ecliptic; for though the ancient observations sufficiently point out a diminution, yet these observations are some of them incompatible, and there is a difference with astronomers of more than one fourth part of the whole annual decrease. This I presume may be determined from some fixed sights that are upon one of the instruments, and which perhaps may be directed to some particular star, or remarkable circle in the heavens.

I am likewise informed that the instruments are divided, but have not been told the particulars; if they have sub-divisions and numbers, they may instruct us in the ancient characters; and perhaps the dimensions of the instruments may give us information respecting the antique measures of the Hindoos; indeed every possible observation ought to be made and every particular dimension taken with the utmost accuracy, for it is with experimental observations as with given situations in geometry where the positions of a few points is sufficient to determine a multitude of lines of different species; and as a number of important conclusions may be drawn from a collection of accurate experiences and well attested facts, so every opportunity of making such ought to be embraced and attended to, if it was on no other account but to give an additional value to observations that might be made in future: For it is worthy of remark that knowledge does not increase in proportion to the number of experiments but in a much higher degree; and that a single observation which proves little or nothing when alone may have a very great effect in conjunction with others; thus, for example, a single point in geometry determines nothing; and two, only give the position of a line; yet if a couple of additional points be added; not only six right lines are thereby determined, but also the magnitude and position of four circles and a parabola; and if we add two points more (which singly would only give a line) we shall thereby determine 15 right lines; 20 circles; 15 parabolas; and 6 ellipses or hyperbolas; from where might be drawn an infinity of other conclusions of different kinds; and though the enquiry at first, might only respect some particular case (as right lines for instance in the example before us) yet from the same data all the rest are deducible; and by similar reasoning, observations made at Benares with only an astronomical view, might be applicable to commerce, to history, chronology, and most kinds of subjects.

There seems reason to conjecture that the sciences took their rise in India, and were carried there to a high degree of perfection before they were transplanted in other countries: This transplantation might be more or less partial according to the inclination or abilities of those that came into India for instruction; and by the intermixture of these with their own different tenets, we may perhaps account for that confused jumble of truth and fiction that we meet with in what are called the *placits* of the philosophers. If the Indians knew the theory of comets and had reduced them to calculation, the Chaldeans from thence might have easily learnt that *comets were only planets moving in very eccentric orbits*, without being able either to calculate their places or to find their distance. To tell us that Pythagoras had the same idea, is only an additional confirmation; we know that he went to India to be instructed; but the capacity of the learner determines his degree of proficiency, and if Pythagoras on his return had so little knowledge in geometry as to consider the forty-seventh of Euclid as a great discovery, he certainly was entirely incapable of acquiring the Indian method of calculation, through his deficiency of preparatory knowledge; and therefore could only get such general notions and principles of things as he was capable of understanding; as the system of the universe, the idea of comets, the plurality of worlds and the doctrine of transmigration: this also accounts for the contradictory opinions of ancient authors concerning the invention of the sciences, and whether the Chaldeans were capable or incapable of predicting the returns of comets and foretelling eclipses, as authors dispute; for each teacher, or head of sect that drew his knowledge from the Indian sources, might conceal his instructors to be reckoned an inventor, and the art itself would be estimated according to the capacity or proficiency of the promulgator, or his followers; thus Berosus the Chaldean is considered by Vitruvius as the inventor of concave sun-dials, though probably the invention had come from the Bramins, as there is now a similar instrument at Benares. Another reason why the sciences were perfected in India is the Indians having been much longer civilised than any other nation, and we know that when people are civilised they begin to study the arts. That they have been much longer civilised, is plain from their state at present, for notwithstanding the slowness of its revolution they have evidently gone through almost the whole political circle of legislative degradation; and are nearly arrived to that despicable state of feeble insignificance, which separates the barbarity of a state of nature, from that of a state of society; and which has all the miseries of both, without any of the advantages of the former.

As it is probable that many of the observations made by Indian astronomers are recorded in manuscript which a more general intercourse with the natives may discover, it becomes the more necessary on that account to make a particular examination of the instruments at Benares, even to enable us to use such observations, if they should chance to be found hereafter; this will appear indispensably requisite, when we consider that the Chinese have their measures of a degree different from ours and that 23, 39', 18", of our divisions make just 24 in China. Now it would have been impossible for us to have made use of these observations had not a comparison between the Chinese instruments and ours enabled Father Gaubil to give us the ratio between them; and as the observatory at Benares is probably the only one existing in India, so no opportunity of examination ought to be neglected, lest the instruments should be defaced by accident or barbarism, and observation be thus rendered useless that might perhaps have been accumulating for ages; at least this advantage will arise from it, that we shall know what mode of angular sub-divisions they really did follow, and from thence probably be enabled to determine whether the astronomers of India had any communication with the Chinese or Arabian & c.

In the Newtonian chronology it is supposed that Chiron made a sphere, and formed the constellation into such figures, respecting the argonautic expedition, as we now have upon our globes; as Aries for the golden fleece; Taurus for the brazen footed bull; Gemini for the two Argonauts, Castor and Pollux & c; this chronology is partly founded on a supposition that Chiron’s sphere was made for the use of the Argonauts and that the equinoctian coloure* at that time passed through the middle of the constellation Aries. This hypothesis, however, has met with great contradictions, for it is positively asserted that the Hindoos have similar constellations, and figured almost exactly in the same manner as those that are attributed to Chiron. Now either Chiron received his sphere from the Indians and the improbability of the coloures* position whence he received it will render the time of the Argonautic expedition doubtful; or else the Indians had their astronomy from the Greeks and therefore may have some of their other productions; at least it implies a communication, and it is probably that not only the true system of the world but many parts of the Grecian literature might be derived from the Bramins. Indeed there are many reasons to believe that the true system extended over many other nations before it was heard of in Greece, for it would have been useless to have multiplied astronomical observations on a false hypothesis and we know that the Babylonian astronomers had a series of near 2000 years observations at the time of Alexander the Great. As to the orbs and epicycles of Ptolemy they are but of modern date, in comparison with the ancient Pythagorean system; and the ignorance of the later Greeks and Romans is evident from the ridiculous explications of ancient monuments (plainly relating to the true system) given by some of the old mythologists, examples of which mode are seen in Boulanger, Costard and others, and I have lately met with a similar instance in the Imag Deorum* of V. Catori, respecting the copy of an ancient Persian monument, in which Apollo dragging a bullock by the horns, apparently has a relation to the doctrine of mutual attraction; and where the figure of the sun in a circular plain intersecting a cone, evidently points out both the centre of force and the form of the earth's orbit; in the same manner that Bullialdus has done in his treatise on the philosaic astronomy.

It would appear from this explanation that the figure of an ox was a symbol with the Persians to represent the moon; perhaps it may also be the same in India, where we know both the moon and the cows are objects of superstitious veneration. There likewise seems to be a familiarity between the East Indians and the Jews; for the Jews *worshipped a calf; baked cakes to the queen of heaven and blew the trumpet in the new moon*, and there is one of their idolatrous customs mentioned in the 7th chapter of Acts and the 5th chapter of Amos, that has a very evident reference to the Hindoo custom of dragging their wooden...* about; and the Jews are threatened to be carried away 'beyond Babylon' for using it; that is, I suppose the place they got it from; for they could not be carried far beyond Babylon without approaching very near the East Indies: However an examination into the Hindoo monuments might give some light into obscure passages of scripture, and as such infinite pains have been spent upon it as a matter of faith, it might not be amiss to take a little more with it, on the footing of a history.

It is usual to speak slightingly of Indian astronomers, and to affirm that the utmost of their learning consists in foretelling an eclipse: But to calculate an eclipse is no trifling matter even in our astronomy, and if the Bramins have such short and easy modes of computation as to make that business a trifle, to gain their methods is certainly an object worthy of enquiry, and the more so as our modes of calculation are excessively tedious and intricate: It is also reported that the Bramins have rules for computing the returns of places of comets. Now this is a matter astonishingly difficult and so complicated with every principle of mechanics and philosophy, that if they can possibly do it there requires (in my opinion) no other proof of their having formerly carried astronomy to the highest degree of perfection.

It is also generally reported that the Bramins calculate their eclipses, not by astronomical tables as we do, but by rules; now these rules, are either as exact as our methods, or not; if they are not, perhaps they may be some particular modes of applying the Chaldean 'saros' of 223 lunation, or the 'neros'* of 600 years, which may be of use in making a near estimate of the times when eclipses may happen: If they be as exact as ours, or but nearly so, it is a proof that they must have carried algebraic computation to a very extraordinary pitch, and have well understood the doctrine of 'continued fractions', in order to have found those periodical approximations; this I am the more confirmed in because I have heard that the Bramins have different rules for computing eclipses and that those rules are more or less complex according to the requisite degrees of exactness; which entirely agrees with the approximation deduced from algebraic formulae, and implies an intimate acquaintance with the Newtonian doctrine of series. This at first sight may seem improbable, but will appear entirely consistent when we recollect that the Bramins have Arabic treatises among them, and that the Arabs are well known to have carried Algebra to a high degree of perfection: We are even told that they had a complete method of resolving cubic equations, and were likewise possessed of the 13 books of Diophantus, the 7 last are lost; in the 6 that remain he has carried the subject almost as far as we have, and therefore it is not impossible for the Bramins to have understood Algebra better than we do.

I have hitherto supposed the Observatory to be ancient, but most of the aforesaid advantages will obtain, even if it be so modern as the reign of Akbar: There will likewise be a greater probability of meeting with the original observations, and more certainly respecting the manner they were taken; as to the system itself which the modern Bramins may now either follow or pretend to follow, it can have no effect upon the observations, for observations are of no sect or party but that of truth, whether the Observatory be Ptolemaics or Copernicans, and if they should happen to be numerous and to be made with great care, they may be of essential service to modern astronomy whether the earth be supposed moveable or immoveable.

I am far from attributing any superior excellence to the present race of Bramins, especially those of the districts about Calcutta, but I am of opinion that a great deal of knowledge may be found in their books and that some curious and useful matters may be learnt from among themselves: Of the skill and abilities of the ancient Bramins I have not the least doubt, though it is a matter of difficulty how long their successors might have retained that knowledge: I am even of opinion that the intent of the first Indian legislature in the institution of the caste of the Bramins was something similar to that of the late society of the Jesuits, and the *Chaldean Astronomers*, the *Persian Magi*, the *Sooth Sayers of Babylon*, the *wise men of the East* and all the *astrologers, stargazers, and magicians* that the prophets of the Bible seem to be afraid of, and yet affect to ridicule, were nothing more than either the Bramins themselves or some of their disciples that were infected with the rage of governing, and giving advice, and travelled about to every court and kingdom like the Jesuits, making use of their knowledge in the sciences as a recommendation to matters of more importance: It would be too long to enumerate reasons for this opinion from history; I shall therefore only just hint that the sun-dial of Ahaz mentioned in scripture seems to have been made by the Bramins of Hindoostan; for the shadow of a sun-dial made for the latitude of Jerusalem could not possibly have gone back, as that of the dial of Ahaz did, and consequently the dial was made for some place between the tropics, and its style must have also been a gnomon; but we know that a dial made for any particular latitude will also serve for another if it is properly drawn and situated, and as the Jews were too ignorant to place it themselves, some Bramin might have done it (for we know that Ahaz followed almost every particular of the Gentoo worship and also encouraged their customs and arts) and Isaiah of course had taken the opportunity to retail its usual property, as a miracle: That the shadow of a sun-dial made for the latitude of Jerusalem can not possibly go back is evident from this principle, that whenever the latitude of the place and the declination of the sun are of the same name, and the latitude less than the declination; the foot of the gnomon will fall without the convex part of the hyperbola described by the shadow; and consequently a tangent may be drawn from that point to the curve, which shows when the shadow goes back; but that the gnomon fall wholly within conic section in all other cases; and from this principle I discovered in my way to India a method of working azimuths at sea between the tropics that may be done with 1/20th part of the trouble of the usual methods, and gives the variation of the compass much more exact.

From the accounts given in the Bible of idolatries of Ahaz and several other of the Israelitic kings, it seems probable that the Gentoo religion had extended itself over most of the kingdoms between India and the Mediterranean; the Jews were continually running into it and made 'carved and molten images', worshipped in *Groves under green trees* and made their sons and daughters *pass through the fire* in the same manner as the Fakeers and Bramins do at present; in short the worship of fire seems to have been a principal part of the Jewish idolatry as it was then all over India and is now on the coast of Malabar. But whether the making of 'their children pass through the fire' was actually sacrificing them, or not, I can not determine; I think it was; but it is worth enquiry what the customs of the fire worshippers on the coast of Malabar are in that respect, and how far those customs extend, and whether there are yet any remains of them among the priests at Benares, as I think there must.

Our knowledge respecting India is so exceedingly confined that it is impossible to conjecture with any degree of probability how the Bramins retained their superiority in literature; it is said that the Ptolemaic system was introduced by one of their conquerors called Bickerammjeet about —(Blank in original—*Editor*) years ago, and that in consequent of his order, the true system of the world was entirely exploded. But part of this story seems more plausible than true for it does not appear likely that men who were strongly convinced of the truth of a system should so easily discard, without ever resuming it, for another that had no other recommendation but the sanction of imperial stupidity. It is more probable that the ancient system kept its ground long after, in private, though the Bramins might pretend to be obsequious to the mandates of authority in public: This at least, is the case now in the Catholic parts of Europe, for by the Pope's decree, to believe in the Copernican system is heresy, and to profess it publicly, is damnation, and yet it is publicly denied and privately believed by every person of knowledge. How far an increase of ignorance may have been favourable to Ptolemy's system in India can only be known by a more intimate acquaintance with the writings of the Bramins; however as this change of system aforesaid, was not at such a vast distance of time, it is to be hoped that the decrease of true knowledge was but slow, and if so, probably some of their best productions may have escaped the ravages of time, and come down to us without much loss or depravation.

Astronomy is a subject that requires a larger stock of mathematical knowledge than is usually imagined, and therefore on the renewal of learning previous to the building of the Observatory at Benares, supposing it modern, there must have been some proficiency made in the sciences; this proficiency must either have been derived from the works of the ancient Bramins, or else introduced from some other country; if it was derived from the Bramins, their books must be still in existence, and therefore might be procured without much difficulty; if from any other nation, it would be of consequence to know with certainty its situation, because we should not only know where to direct our enquiries but that nation it is reasonable to suppose would have made collection of all the learning of the adjacent and neighbouring countries, and would in particular have procured, and yet might retain, the works of the principal Arabian mathematicians; but the Arabian mathematicians we know were possessed of most of the works of the Greeks (for it is from straggling Arabic manuscripts picked up by chance, that we derive the little we know of Grecian mathematics) and therefore to determine the source of these, will be perhaps to discover those excellent works of Archimedes, Euclid, Diophantus and Apollonius & c. that have been so long lost and deplored by European mathematicians.

But supposing after all that his Observatory (contrary to every rule of probability) was built for ostentation and not for use; that there is nothing in its construction worth remarking; no observations on record to be met with, nor any appearance of utility to be derived either from its situation, its form, or position of the instruments, yet even in that case the expense will not be entirely lost; for a number of observations may be made respecting the geography, meteorology and astronomy & c. of India that will more than compensate the trouble. The surveys of India are known to be remarkably defective, and there is great reason to believe that not a single place in India has had its longitude properly determined except Pondicherry. The latitudes are nearly in the same predicament, and indeed most of the English maps are made up of ideal chains of mountains and imaginary woods, taken piecemeal by pretended surveyors, and put together at random without either longitude or latitude by people who were only solicitous to have a fine drawing, without any regard to exactness or to use; by these means the countries are horribly distorted in their positions and geography is so little benefitted by such maps that they are a nuisance rather than an advantage, and there is no other proper method of correcting such surveys but by determining the positions of some of the most material points by astronomical observations; this would assist in putting the different surveys properly together, and as the longitude of Benares and others that might be deduced from it, would contribute in part to that purpose, a journey thither of course would be so far useful.

The opportunity of making observations of the dip, and variation of the compass might have then utility not only in correcting the surveys, but in discovering the theory of magnetism: that the theory has not yet been discovered is in my opinion owing to a want of observations: It is not easy to know conclusions by induction without a sufficiency of facts, and yet I do not know that in the whole space from India to the frozen ocean, nor from Persia to Kamchatka there has yet been made a single observation, except that at Tobolski by De La Chappe..., and therefore a journey to Benares would also be useful in this matter.

The nature of the refraction and its variation with respect to the heat, moisture and density of the air, would also be a very proper object of enquiry at Benares: The tables made by Cassini, Newton and de La Caille, are all of them different, and with respect to Benares, are adapted to very extreme latitudes: There is also reason to believe that the results at Benares would be very different from any of them and not only elucidate the general principles of refraction, but also be of service in the practice of navigation, especially about the tropics; if any ancient observations should be discovered, the refraction would be absolutely necessary, and even if they should not, it would have its use; for the climates of England and India are different, to depend upon reasoning from analogy only; especially when there are so many causes of variations and so few of them well determined.

If the observer was furnished with a proper instrument, it would also be advisable to find the moon’s horizontal parallax in the manner first hinted by Digges and afterwards employed by Maskelyne at St Helena: This would in some respect answer the purpose of measuring a degree of the meridian, especially as the errors might be reduced to very small limits by a repetition of the observations; and this method has an advantage over that of measuring a degree, for it is not liable to be affected by the uncertain attraction of mountains.

With respect to the other observations respecting meteorology, aerometry, astronomy and electricity & c. which a journey to Benares would give an opportunity of making, it would be endless to enumerate the particulars: It is sufficient to observe that they would all be of service to philosophy, and not take any extraordinary time to execute. But if it was thought proper to send a person who was well acquainted with the theory and practice of astronomy & c. with a small collection of good instruments to take the latitudes and longitudes of most of the particular towns and places in the Company's territories and dependencies, he might not only collect materials for making a proper survey of these parts and acquire information respecting the ancient and modern state of the country & c. but would also have an opportunity of making the best collection of astronomical and physical observations that has yet been offered to the public; and if it was thought that umbrage might be taken at such a procedure by the natives, it might easily pass under the notion of measuring degrees of the meridian, or of longitude & c., to avoid suspicion.

IV

ON THE SIXTH SATELLITE OF SATURN

(*From Col. T.D. Pearse to Secretary, Royal Society, London
(dated, Madras 22 September 1783).)

The small book, that accompanies this letter, written in the Persian language, is a copy of part of a very large one in the same language, entitled 'The Wonders of the Creation', and it is in fact a kind of general natural history, extracted by the compiler from books of science, and of voyages and travels, performed by the Arabians, who it is well known had, not only a great foreign trade, but extensive settlements in the islands of the East Indies, where yet their manners and religion do still prevail. I beg you to present it to the society in my name.

The book opens with an account of the wonders of the heavens, and the celestial spheres; the system is the Ptolemaic. To each except Mars and Jupiter, figures are annexed and blank spaces were left in the book I used, for the figures of those planets. You will see that, the sun and moon are drawn as amongst us, Mercury is represented as in the act of writing, with paper and pen in his hands, and the inkpot before him; Venus is a woman sitting down, and playing upon a stringed instrument, resembling an Irish harp. And that, which occasions this letter, is the figure of Saturn. By enquiry amongst the learned of these parts, Mars ought to be represented as a warrior, and Jupiter as an old man sitting down, with four girls dancing round him: the book says something contrary to this. I never saw the figure, therefore simply relate what was told me.

The book was written in fifth or sixth century of the Hijera, and that which I borrowed, and from which my copy was taken, is in the possession of Mr Palk, in which the figures are all paintings, but the age of that copy I can not tell, being at a great distance.

It is now time to tell you, why I trouble you with the book: tho I must first inform you that, I had it copied, solely for the sake of the figures of Saturn, and had begun to translate the part that treated of the celestial bodies to send home, with a copy of the original, to the illustrious society, about four years ago: but the difficulty of getting the figure drawn prevented the carrying my design into execution. However in the year 1780, having got what I wanted, I sat down to do my part, but the war with Hyder Allee carried me from home, into the Carnatic; and tho I have had the part that was intended for the society, with me, the whole time, yet I really had not time to translate it, except the small part that ascertain the age of the book, and the account of Saturn; in which there is not, however, any mention of the satellites, or ring or anything else; and the account of his periodic time is erroneous, and plainly relates to the seventh planet, the period of which is about sixty years and which is very seldom seen, and when seen is deemed ominous to the world in general, so says the learned Bramin with whom I talked. The instant I saw the figure it struck me as emblematical of Saturn, and as representing him possessed of what till very lately we were ignorant, I mean his satellites and ring. Hitherto only five satellites have been seen by Europeans; he is here represented as having six, and their names I presume are expressed by the figures held in the hands: the arms show that these bodies are moveable, but can not separate from the planet, and are capable of various motions within certain distances. The seventh holds the crown which is divided into four parts and this I suppose to mean the four concentric parts of the ring. The darkness, under the arm which holds the ring, denotes that the ring does not everywhere touch the body, and that there is a passage between it, and the body of the planet. The legs folded beneath the body I imagine to relate also to the ring and to intimate that, the ring supports the body of the planet, or at least, that the body appears to rest upon, or within it: I conceive that the long beard, and emaciated body denote age, and represent the flowing of his motions.

If it be urged that this explanation can not be put, for that the ancients had not instruments capable of showing them, I answer it is more than we can prove, and if ever a sixth satellite be discovered, it will be a strong argument in favour of the contrary opinion. I am much inclined to believe they had better instruments than we have. I must in this letter aim at brevity, therefore shall only say, that Alhazan wrote on colours, and [catoptricks], and the problem for finding the figures of objects, reflected from convex specula, is called Alhazan to this day. I have not seen Alhazan; if I could get it, I could with the assistance this country would afford me, come at the knowledge of its contents, and perhaps might find telescopes. But if not, it does not seem any argument against there having been such instruments. For we know how early manuscripts are lost and of such books, as those which treat of subjects, in which only the learned, in particular sciences, are concerned, the number of copies will have been few. Even now (when such) number of copies of such books are published, do we not find that many are lost, or only to be found in very extensive libraries? Much more easily then might the same thing disappear, before, when only manuscripts were in use. And when we reflect how few men in any country make use of telescopes, and quadrants and such like instruments, we may easily conceive, that the copies of books treating of such matters would be very few, compared with astronomical tables, which were in greater use, on account of their utility in astrology: and those are scarce, and it is difficult for Europeans to get them.

I shall now address some thing approaching to a proof of there having been telescopes, tho perhaps not like ours. First then, I asked a learned mussulman with whom I had frequent conversations on these subjects, whether they had any mention of such instruments as we use; he said he did not recollect that there were any, except Alhazan, amongst the Arabs, who (ever) that he knew had written on such subjects. Nor do I know added he, that he did describe such instruments, but he treats of the principles on which they depend.

I must now observe, that since Alhazan wrote on colours, and reflection; if not on refractions through prisms and lenses, the not finding any mention of the uses, to which the specular were applied, will certainly not prove that there were no telescopes.

Let us suppose a treatise, on reflection and refraction and the places of figures formed by either, to be written purely scientifically, without any mention of telescopes, or any application of the uses of the theorems. That by some accident, (possibly from the revolutions of time) all other treatises on the subject, or books in which telescopes, and their uses are described, and all telescopes had perished. If such treatise were then to be found, in some very remote period, the finder would not easily discover the use of the theorems, and still less the instruments formed on the principles, therein delivered. Alhazan delivered principles. Artists might possess the application, perhaps not even committed to writing, but learned, as trades are now learnt, by working and practice.

A Bramin with whom, I discoursed, and asked how they made their tables, said that they were formed a long while ago, by means of great pits, dug into the earth, in which the celestial bodies were made visible. But what means they used to see them he did not know. He said he could only use these tables, not form them; that the sun had formerly delivered the tables to a learned Bramin, who had continued above sixty years constantly adoring him, as a reward for his labours. The Bramin agreed, that what he said was allegorical, and simply meant that they were formed by a series of observations, diligently made. So little could I make from these discourses, that instead of gaining lights I seemed rather to lose them; and tho the mussulman thought of Alhazan as I do, (and moreover told me that the observation of the transit of venus, made by our horrox, which I reduced to the Hijera, was not the first; for that mention is made of one a long period before that, in an Arabic book; he quoted the name, which I have forgotten but have in Bengal, amongst my papers) yet the want of actual knowledge of the use of telescopes threw all into doubt. However one day as I was reading an English translation of the Arabian Nights, I met with mention of them as things of very common use, and compared with things as common as apples, and carpets. Three princes went to seek for curiosities, and the fairee Purree Baunoo furnished each, under different shapes, with what he wanted; to one she sold a small carpet for an immense price, not from its curious texture, but its property of transporting him, that sat on it, to the place to which he wished to go; to the second an apple, that would cure disorders by being laid on a sick person; and for the same price, she sold to the third a telescope, that was endowed with the property of showing to him that looked through it, what he wished to see, if he looked through one end; and objects as usual if he looked through the other: and it is described as a small tube of ivory, having a glass at each end.

If then that book were written before telescopes were in use in Europe, and that is ascertainable, then telescopes were things in common use, before we had any ideas of them; and tho they are not described as being such as Dollond has since made, they were telescopes, and amongst those who even now mention telescopes occasionally, how few will describe those exquisite ones, that are applied to astronomical purposes. That useful inventions perish, in time, have we not instances enough. The mummies suffice; tho even in our own days have we not seen Dollond perfect telescopes, by the addition of three object glasses, and are we not in danger of losing them again, from the want of the materials to make one of the kinds of glass used by him? Gun powder is also thought to be, as I may call it, compared with great antiquity, a modern invention; and yet in Gray's Gunnery, there is a quotation from a Greek author, that gives reason enough to suppose, it was applied to guns, even in the time of Alexander.

Much more I could add on this subject, and had written in Bengal, to send you, but in my present situation I can only add, that the loss of any science is not a proof that it never was known, and all I propose, is to present the figure of Saturn as I found it, and to give you my reason for explaining the emblem as I have done: which yet remains to be made out, by some future discovery, of the sixth satellite, the existence of which is not thought to be totally chimerical.

I shall not scruple to inform you of things that may seem wonderful, which come within my own knowledge. I have the prediction of three comets and an earthquake, which I received long before the events. The earthquake did actually happen, and desolated the extensive regions, round Lahore. Unfortunately that paper is in Bengal. Mr Hastings has a copy of it signed by me, with the day marked on the paper, to show when I received it, which was June and I think the earthquake happened in September, or the latter end of August 1779 or 1780. But I send you the copies of the other two predictions, one of which was fully verified at Bath, tho I, being on my march, had not time to look for it, as I certainly should have done, had I been settled.

The Bramin has promised to me a copy of the tables of one hundred and eight comets; and when I return to Bengal, if he is living, I will endeavour to get them. He says they are of different kinds, some have straight tails, some crooked tails, some fan tails some are encircled with a burr, and some are without any. Again some are retrograde, some [direct] and others cross the heavens; I hardly dare to tell you, that the book was, as he says, written in the *jugg* preceding this, and that this began, with what we call the creation.

When we are arrived at some knowledge of the Sanscrit, we may make discoveries of much importance, and either verify the assertions or contradict them. I relate simply what was told to me, I do not take upon me to vouch any thing, but that the man had not any interest in deceiving me; I asked for information, after the manner of a disciple; proposed questions arising from the discourse, and making comparison of what he said, with our system, for further information. He replied, you and the mussulmans differ, from each other and from us; the mussulmans suppose the sun to go round the earth, daily, and annually; but the earth turns round its axis daily, according to your system, and to ours; mussulmans follow Ptolemy, we the ancient books, and you a system of your own, if not derived from ours.

Here I must put an end to a letter, which I fear, will prove tedious, more especially as it concerns matters, which militates with systems, that men do not wish to (spake); and which I relate merely to show some part of the belief, of some of the men of science of the Hindoo tribe, who are not very communicative.

V

A PROOF THAT THE HINDOOS HAD THE BINOMIAL THEOREM

(By Reuben Burrow (Published 1790))

The Islands in the Bay of Bengal are many of them covered with shells and marine productions to a great height, and there are beds of large smooth pebbles near the Herdwar some hundreds of feet above the present level of the Ganges; the sea has therefore gradually been retiring, and consequently the position of the Equator was formerly farther north than it is at present in this part of the earth; and if a few similar observations were made in other countries, it is evident that the ancient situation of the Pole upon the surface of the earth might be determined sufficiently near for explaining many difficulties and paradoxes in geographical antiquities, for this purpose also it would be advisable to have permanent meridian lines drawn in high northern latitudes, to be compared in succeeding ages, and also to have marks cut upon rocks in the sea to show the proper level of the water.

In the aforesaid position of the Equator the sands of Tartary were inhabitable and the Siberian climates temperate; the deserts of the lesser Bukharia were then part of the seat of the Paradise of Moses; and the four sacred rivers of Eden went through India, China, Siberia, and into the Caspian Sea, respectively: this appears from a Bramin map of the world in the Sanscrit language which I met with about two years ago in the higher parts of India, together with a valuable Treatise of Geography upon the system of Boodh; both of which I communicated with my idea on the subject to Mr Wilford, of the Bengal Engineers; and from him the world may expect shortly to be favoured with the first true representation of Scriptural and Hindoo Geography.

From the aforesaid country the Hindoo religion probably spread over the whole earth: there are signs of it in every northern country, and in almost every system of worship: in England it is obvious; Stonehenge is evidently one of the temples of Boodh; and the Arithmetic, the Astronomy, Astrology, the Holidays, Games, names of the Stars and figures of the Constellations; the ancient Monuments, Laws, and even the languages of the different nations have the strongest marks of the same original. The worship of the sun and fire; human and animal sacrifices, & c. have apparently once been universal: the religious ceremonies of the papists seem in many parts to be a mere servile copy of those of the Goseigns and Fakeers; the Christian Ascetics were very little different from their filthy original the Byraggys, & c.; even the hell of the northern nations is not at all like the hell of the scripture, except in some few particulars; but it is so striking a likeness of the hell of the Hindoos that I should not at all be surprised if the story of the soldier that saw it in Saint Patrick's purgatory, described in Matthew Paris's history, should hereafter turn out to be merely a translation from the Sanscrit with the names changed. The different tenets of Popery and Deism have a great similarity to the two doctrines of Brahma and Boodh, and as the Bramins were the authors of the Ptolemaic system, so the Boodhists appear to have been the inventors of the ancient Philolaic or Copernican, as well as of the doctrine of attraction; and probably too the established religion of the Greeks and the Eleusinian mysteries may only be varieties of the two different sects. That the Druids of Britain were Bramins is beyond the least shadow of a doubt; but that they were all murdered and their sciences lost, is out of the bounds of probability; it is much more likely that they turned school-masters and freemasons and fortune tellers, and in this way part of their sciences might easily descend posterity, as we find they have done; an old paper said to have been found by Locke bears a considerable degree of internal evidence both of its own antiquity and of this idea; and on this hypotheses it will be easy to account for many difficult matters that perhaps cannot so clearly be done on any other, and particularly of the great similarity between the Hindoo sciences and ours; a comparison between our oldest scientific writers and those of the Hindoos will set the matter beyond dispute, and fortunately the works of Bede carry us twelve hundred years back, which is near enough to the times of the Druids to give hopes of finding there some of their remains: I should have made the comparison myself but Bede is not an author to be met within this country; however, I compared an Astrolabe in the Nagry character (brought by Dr Mackinnon from Jynagur) with Chaucer's description, and found them to agree most minutely, even the centre pin which Chaucer calls 'the horse' has a horse's head upon it in the instrument; therefore if Chaucer's description should happen to be a translation from *Bede* it will be a strong argument in favour of the hypothesis, for we then could have nothing from the Arabians: what Bungey and Swisset may contain, will also deserve enquiry, and that the comparison may be the readier made, where the books are procurable, I mean very shortly to publish translations of the *Lilavati* and *Beej Ganeta*, or the Arithmetic and Algebra of the Hindoos.

It is much to be feared, however, that many of the best treatises of the Hindoos are lost, and that many of those that remain are imperfect; by the help of a Pundit I translated part of the *Beej Ganeta* near six years ago when no European but myself, I believe, even suspected that the Hindoos had any Algebra, but finding that my copy was imperfect I deferred completing the translation in hopes of procuring the remainder; I have since found a small part more, and have seen many copies, but from the plan of the work (which in my opinion is the best way of judging) they still seem all to be imperfect, though the copier generally takes care to put at the end of them that they are complete. I have the same opinion of the *Lilavati*, and for the same reason; indeed it is obvious that there must have been treatises existing where Algebra was carried much farther; because many of their rules in Astronomy are approximations deduced from infinite series; or at least have every appearance of it; such for instance as finding the sine from the arc, and the contrary; and finding the angles of a right angled triangle from the hypothenuse and sides, independent of tables of sines; and several others of a similar nature much more complicated. I have been informed by one of their Pundits, that some time ago, there were other treatises of Algebra, besides that just mentioned, and much more difficult, though he had not seen them; and therefore, as it is possible they may still be existing, and yet be in danger of perishing very soon, it is much to be wished that people would collect as many of the books of science as possible; (their poetry is in no danger, and particularly those of the doctrine of Boodh which perhaps may be met with towards Tibet. That many of their best books are depraved and lost is evident, because there is not now a single book of geometrical elements to be met with; and yet that they had elements not long ago, and apparently more extensive than those of Euclid is obvious from some of their works of no great antiquity: the same remarks are applicable to their cosmographical remains, in some of which there are indications of an Astronomy superior to that of the *Soorya Siddhant*, and such popular treatises.

Till we can therefore find some of their more superior works, it must be rather from the form and construction of their astronomical tables and rules, and the properties implied in their accidental solutions of questions, & c., that we can judge what they formally knew, than otherwise; that they were acquainted with a differential method similar to Newton's, I shall give many reasons for believing, in a treatise on the principles of the Hindoo Astronomy, which I began more than three years ago, but was prevented from finishing, by a troublesome and laborious employment that for two years gave me no leisure whatever; and which (though the short time I had to spare since has been employed in writing a comment on the works of Newton, and explaining them to a very ingenious native who is translating them into Arabic) I hope ere long to have an opportunity of completing: at present I shall only give an extract of a paper explaining the construction of some tables, which first led me to the idea of their having a differential method; it is part of one out of a number of papers that were written in the latter part of the year 1783, and the beginning of 1784, and of which several copies were taken by different people, and some of them sent to England: this particular extract, was to investigate the rules at pages 253, 254 and 255, of Mons. Gentil's Voyage, of which the author says, '*Je n'ai pu savoir sur quels principes cette table est fondee, & c.*,' and is as follows:

'Now by proceeding in the manner explained in the aforesaid paper to calculate the right ascension and ascensional difference for Tirvalour, and afterwards taking the differences algebraically, and reducing them to *puls* of a *gurry* as in the following table, the principles of the method will be evident. *(Table on the following page)*

'The fifth and sixth columns sufficiently explain the tables in pages 253 and 254 of Mons. Gentil, but there remains a part more difficult, namely, why in calculating the *Bauja*,' or the doubles of the first differences of the ascensional difference '20/60 of the length of the shadow is taken for the first; 4/5 of the first term for the second, and 1/3 of the first term for the third.' 'The primary reason of taking differences here, seems to be that the chords may be nearly equal to the arcs, and that, by adding of the differences, the arcs themselves may be found nearly; the reason will appear from the following investigation. Let N be the equatorial shadow of the Bramins in *bingles*; then 720 the length of the Gnomon, or twelve *ongles*, will be to N the shadow, as radius to the tangent of the latitude; and radius to the tangent of the latitude as the tangent of the declination to the sine of the ascensional difference; consequently 720 is to N as the tangent of declination to the sine of the ascensional difference. Now if the declinations for one, two, and three signs be substituted in the last proportion, we get the sines of the three ascensional differences in terms of N and known quantities; and, if these values be substituted in the Newtonian form for finding the arc from the sine, we get the arcs in parts of the radius; and if each of these be multiplied by 3600 and divided by 6,28318, the values come out in *puls* of a *gurry* if N be in *bingles*, but in parts of a *gurry* if N be in *ongles*; and by taking the doubles we get the values nearly as follows:

'Now because the values in the first column are doubles of the ascensional differences for one, two and three signs, their halves are the ascensional differences in parts of a *gurry*, supposing N to be in *ongles*; and if each of these halves be multiplied by sixty, the products, namely, 9,9168 N; 17,9784 N; and 21,2580 N will be the same in *puls* of a *gurry*; and if to get each of these nearly, in round numbers, the whole be multiplied by three, and afterwards divided by three, the three products will be 29.75 N; 53.94 N, and 63.77 N which are nearly equal to thirty N; fifty-four N, and sixty-four N respectively; and hence the foundation of the Bramin rule is evident, which directs to multiply the equatorial shadow by thirty, fifty-four, and sixty-four, respectively; and to divide the products by three for the Chorardo in *puls*: and these parts answer to one, two, and three signs of longitude from the true Equinox and therefore the *Ayanongsh*, or Bramin precession of the Equinox, must be added to find the intermediate Chorardo by proportion.'

Though the agreement of this investigation with the Bramin results, is no proof that the Hindoos had either the differential method, or Algebra; it gave me at the time a strong suspicion of both; and yet for want of knowing the name that Algebra went by in Sanscrit, it was near two years before I found a treatise on it, and even then I should not have known what to enquire for, if it had not come into my mind to ask how they investigated their rules: of the differential method I have yet met with no regular treatise, but have no doubt whatever that there were such, for the reasons I before hinted at, and I hope others will be more fortunate in their enquiries after it than myself.

With respect to the Binomial Theorem, the application of it to fractional indices will perhaps remain for ever the exclusive property of Newton; but the following question and its solution evidently show that the Hindoos understood it in whole numbers to the full as well as Briggs, and much better than Pascal. Dr Hutton, in a valuable edition of Sherwin's tables, has lately done justice to Briggs; but Mr Witchell, who some years before pointed out Briggs as the undoubted inventor of the differential method, said he had found some indications of the Binomial Theorem in much older authors: the method however by which that great man investigated the powers independent of each other, is exactly the same as that in the following translation from the Sanscrit.

'A Raja's palace had eight doors; now these doors may either be opened by one at a time; or by two at a time; or by three at a time; and so on through the whole, till at last all are opened together: it is required to tell the numbers of times that this can be done?

‘Set down the number of the doors, and proceed in order gradually decreasing by one to unity and then in a contrary order as follows:

8	7	6	5	4	3	2	1
1	2	3	4	5	6	7	8

‘Divide the first number eight by the unit beneath it, and the quotient eight shows the number of times that the doors can be opened by one at a time: multiply this last eight by the next term seven, and divide the product by the two beneath it, and the result twenty-eight is the number of times that two different doors may be opened: multiply the last found twenty-eight by the next figure six, and divide the product by the three beneath it, and the quotient fifty-six, shows the number of times that three different doors may be opened: again this fifty-six multiplied by the next five, and divided by the four beneath it, is seventy, the number of times that four different doors may be opened: in the same manner fifty-six is the number of fives that can be opened: twenty-eight the number of times that six can be opened: eight the number of times that seven can be opened: and lastly, one is the number of times the whole may be opened together, and the sum of all the different times is 255.’

The demonstration is evident to mathematicians; for as the second term’s coefficient in a general equation shows the sum of the roots, therefore in the n power of $1+1$ where every root is unity the coefficient shows the different *ones* that can be taken in n things: also because the third term’s coefficient is the sum of the products of all the different twos of the roots, therefore when each root is unity the product of each two roots will be unity, and therefore the number of units or the coefficient itself shows the number of different *twos* that can be taken in n things. Again because the fourth term is the sum of the products of the different threes that can be taken among the roots, therefore when each root is unity, the product of each three will be unity and therefore every unit in the fourth, will show a product of three different roots, and consequently the coefficient itself shows all the different *threes* that can be taken in n things; and so for the rest. I should not have added this, but that I do not know well where to refer to it.

P.S. There is an observation perhaps worth remarking with respect to the change of the Poles; namely, that the small rock oysters are generally all dead within about a foot above high water mark; now possibly naturalists may be able to tell the age of such shells nearly by their appearance, and if so, a pretty good estimate may be formed of the rate of alteration of the level of the sea in such places where they are; for I made some astronomical observations on a rock in the sea near an island about seven miles to the south of the island of Cheduba on the Aracan coast, whose top was eighteen feet above high water mark, and the whole rock covered with those shells fast grown to it, but all of them dead, except those which were a foot above the high water mark of that day, which was February 2, 1788: the shells were evidently altered a little in proportion to their height above the water, but by no means so much as to induce one to believe that the rock had been many years out of it: all the adjacent islands and the coast showed similar appearances, and therefore it was evidently no partial elevation by subterranean fires, or any thing of that sort: this is also apparent from the island of Cheduba itself, in which there is a regular succession of sea beaches and shells more and more decayed to a great height. By a kind of vague estimation from the trees and the coasts and shells, & c. (on which however there is not the least dependence) I supposed that the sea might be subsiding at the rate of about three inches in a year.

VI

HINDU ALGEBRA

(Given as introduction to 'Algebra with Arithmetic and Mensuration, from the Sanscrit of Brahmegupta and Bhascara' by H.T. Colebrooke (Pub 1817). Diacritical marks on Sanskrit words have been removed - *Editor.*)

The history of sciences, if it want the prepossessing attractions of political history and narration of events, is nevertheless not wholly devoid of interest and instruction. A laudable curiosity prompts to inquire the sources of knowledge; and a review of its progress furnishes suggestions tending to promote the same or some kindred study. We would know the people and the names at least of the individuals, to whom we owe particular discoveries and successive steps in the advancement of knowledge. If no more be obtained by the research, still the inquiry has not been wasted, which points aright the gratitude of mankind.

In the history of mathematical science, it has long been a question to whom the invention of Algebraic analysis is due, among what people, in what region, was it devised, by whom was it cultivated and promoted, or by whose labours was it reduced to form and system? And finally, from what quarter did the diffusion of its knowledge proceed? No doubt indeed is entertained of the source from which it was received immediately by modern Europe; though the channel has been a matter of question. We are well assured, that the Arabs were mediately or immediately our instructors in this study. But the Arabs themselves scarcely pretend to the discovery of Algebra. They were not in general inventors but scholars, during the short period of their successful culture of the sciences: and the germ at least of the Algebraic analysis is to be found among the Greeks in an age not precisely determined, but more than probably anterior to the earliest dawn of civilization among the Arabs: and this science in a more advanced state subsisted among the Hindus prior to the earliest disclosure of it by the Arabians to modern Europe.

The object of the present publication is to exhibit the science in the state in which the Hindus possessed it, by an exact version of the most approved treatise on it in the ancient language of India, with one of the earlier treatises (the only extant one) from which it was compiled. The design of this preliminary dissertation is to deduce from these and from the evidence which will be here offered, the degree of advancement to which the science had arrived in a remote age. Observations will be added, tending to a comparison of the Indian, with the Arabian, the Grecian, and the modern Algebra: and the subject will be left to the consideration of the learned, for a conclusion to be drawn by them from the internal, no less than the external proof, on the question who can best vindicate a claim to the merit of having originally invented or first improved the methods of computation and analysis, which are the groundwork of both the simple and abstruser parts of Mathematics; that is, Arithmetic and Algebra: so far at least as the ancient inventions are affected; and also in particular points, where recent discoveries are concerned.

In the actual advanced condition of the analytic art, it is not hoped, that this version of ancient *Sanscrit* treatises on Algebra, Arithmetic, and Mensuration, will add to the resources of the art, and throw new light on mathematical science, in any other respect, than as concerns its history. Yet the remark may not seem inapposite, that had an earlier version of these treatises been completed, had they been translated and given to the public, when the notice of mathematicians was first drawn to the attainments of the Hindus in astronomy and in sciences connected with it, some addition would have been then made to the means and resources of Algebra for the general solution of problems by methods which have been re-invented, or have been perfected, in the last age.

The treatises in question, which occupy the present volume, are the *Vija-Ganita* and *Lilavati* of Bhascara Acharya and the *Ganitadhyaya* and *Cuttacadhyaya* of Brahmegupta. The two first mentioned constitute the preliminary portion of Bhascara's Course of Astronomy, entitled *Siddhanta-siromani.* The two last are the twelfth and eighteenth chapters of a similar course of astronomy, by Brahmegupta, entitled *Brahma-siddhanta.*

The questions to be first examined in relation to these works are their authenticity and their age. To the consideration of those points we now proceed.

The period when Bhascara, the latest of the authors now named, flourished, and the time when he wrote, are ascertained with unusual precision. He completed his great work, the

Siddhanta-siromani, as he himself informs us in a passage of it,[1] in the year 1072 *Saca*. This information receives corroboration, if any be wanted, from the date of another of his works, the *Carana-cutuhala*, a practical astronomical treatise, the epoch of which is 1105 *Saca*;[2] 33 years subsequent to the completion of the systematic treatise. The date of the *Siddhanta-siromani*, of which the *Vija-Ganita* and *Lilavati* are parts, is fixed then with the utmost exactness, on the most satisfactory grounds, at the middle of the twelfth century of the Christian era, A.D. 1150.[3]

The genuineness of the text is established with no less certainty by numerous commentaries in *Sanscrit*, besides a Persian version of it. Those commentaries comprise a perpetual gloss, in which every passage of the original is noticed and interpreted: and every word of it is repeated and explained. A comparison of them authenticates the text where they agree; and would serve, where they did not, to detect any alterations of it that might have taken place, or variations, if any had crept in, subsequent to the composition of the earliest of them. A careful collation of several commentaries,[4] and of three copies of the original work, has been made; and it will be seen in the notes to the translation how unimportant are the discrepancies.

From comparison and collation, it appears then, that the work of Bhascara, exhibiting the same uniform text, which the modern transcripts of it do, was in the hands of both Mahommedans and Hindus between two and three centuries ago: and, numerous copies of it having been diffused throughout India, at an earlier period, as of a performance held in high estimation, it was the subject of study and habitual reference in countries and places so remote from each other as the north and west of India and the southern peninsula: or, to speak with the utmost precision, *Jambusara* in the west, *Agra* in North *Hindustan*, and *Parthapura, Golagrama, Amaravati*, and *Nandigrama*, in the south.

This, though not marking any extraordinary antiquity, nor approaching to that of the author himself, was a material point to be determined: as there will be in the sequel occasion to show, that modes of analysis, and, in particular, general methods for the solution of indeterminate problems both of the first and second degrees, are taught in the *Vija-Ganita*, and those for the first degree repeated in the *Lilavati*, which were unknown to the mathematicians of the west until invented anew in the last two centuries by algebraists of France and England. It will be also shown, that Bhascara, who himself flourished more than six hundred and fifty years ago, was in this respect a compiler, and took those methods from Indian authors as much more ancient than himself.

That Bhascara's text (meaning the metrical rules and examples, apart from the interspersed gloss) had continued unaltered from the period of the compilation of his work until the age of the commentaries now current, is apparent from the care with which they have noticed its various readings, and the little actual importance of these variations; joined to the consideration, that earlier commentaries, including the author's own explanatory annotations of his text, were extant, and lay before them for consultation and reference. Those earlier commentaries are occasionally cited by name: particularly the *Ganita-caumudi*, which is repeatedly quoted by more than one of the scholiasts.[5]

No doubt then can be reasonably entertained, that we now possess the arithmetic and algebra of Bhascara, as composed and published by him in the middle of the twelfth century of the Christian era. The age of his precursors cannot be determined with equal precision. Let us proceed, however, to examine the evidence, such as we can at present collect, of their antiquity.

Towards the close of his treatise on Algebra,[6] Bhascara informs us, that it is compiled and abridged from the more diffuse works on the same subject, bearing the names of Brahme, (meaning no doubt Brahmegupta) Sridhara and Padmanabha; and in the body of his treatise, he has cited a passage of Sridhara's algebra,[7] and another of Padmanabha's.[8] He repeatedly adverts to preceding writers, and refers to them in general terms, where his commentators understand him to allude to Arya-bhatta, to Brahmegupta, to the latter's scholiast Chaturveda Prithudaca Swami,[9] and to the other writers above mentioned.

Most, if not all, of the treatises, to which he thus alludes, must have been extant, and in the hands of his commentators, when they wrote; as appears from their quotations of them; more especially those of Brahmegupta and Arya-bhatta, who are cited, and particularly the first mentioned, in several instances.[10] A long and diligent research in various parts of India, has, however, failed of recovering any part of the *Padmanabha vija*, (or Algebra of Padmanabha) and of the Algebraic and other works of Arya-bhatta.[11] But the translator has been more fortunate in regard to the works of Sridhara's and Brahmegupta, having in his collection Sridhara's compendium of arithmetic, and a copy, incomplete however, of the text and scholia of Brahmegupta's *Brahma-siddhanta*; comprising among other no less interesting matter, a chapter treating of arithmetic and mensuration; and another, the subject of which is algebra: both of them fortunately complete.[12]

The commentary is a perpetual one; successively quoting at length each verse of the text; proceeding to the interpretation of it, word by word; and subjoining elucidations and remarks: and its colophon, at the close of each chapter, gives the title of the work and name of the author.[13] Now the name, which is there given, Chaturveda Prithudaca Swami, is that of a celebrated scholiast of Brahmegupta, frequently cited as such by the commentators of Bhascara and by other astronomical writers: and the title of the work, *Brahma-siddhanta*, or sometimes *Brahmasphuta-siddhanta*, corresponds, in the shorter form, to the known title of Brahmegupta's treatise in the usual references to it by Bhascara's commentators;[14] and answers, in the longer form, to the designation of it, as indicated in an introductory couplet which is quoted from Brahmegupta by Lacshmidasa, a scholiast of Bhascara.[15]

Remarking this coincidence, the translator proceeded to collate, with the text and commentary, numerous quotations from both, which he found in Bhascara's writings or in those of his expositors. The result confirmed the indication, and established the identity of both text and scholia as Brahmegupta's treatise, and the gloss of Prithudaca. The authenticity of this *Brahma-siddhanta* is further confirmed by numerous quotations in the commentary of Bhattotpala on the *sanhita* of Varahamihira: as the quotations from the *Brahma-siddhanta* in that commentary, (which is the work of an author who flourished eight hundred and fifty years ago) are verified in the copy under consideration. A few instances of both will suffice; and cannot fail to produce conviction.[16]

It is confidently concluded, that the Chapters on Arithmetic and Algebra, fortunately entire in a copy, in many parts imperfect, of Brahmegupta's celebrated work, as here described, are genuine and authentic. It remains to investigate the age of the author.

Mr Davis, who first opened to the public a correct view of the astronomical computations of the Hindus,[17] is of opinion, that Brahmegupta lived in the 7th century of the Christian era.[18] Dr William Hunter, who resided for some time with a British Embassy at *Ujjayani*, and made diligent researches into the remains of Indian science, at that ancient seat of Hindu astronomical knowledge, was there furnished by the learned astronomers whom he consulted, with the ages of the principal ancient authorities. They assigned to Brahmegupta the date of 550 *Saca*; which answers to A.D. 628. The grounds, on which they proceeded, are unfortunately not specified: but, as they gave Bhascara's age correctly, as well as several other dates right, which admit of being verified; it is presumed, that they had grounds, though unexplained, for the information which they communicated.[19]

Mr Bentley, who is little disposed to favour the antiquity of an Indian astronomer, has given his reasons for considering the astronomical system which Brahmegupta teaches, to be between twelve and thirteen hundred years old (1263 years in A.D. 1799).[20] Now, as the system taught by this author is professedly one corrected and adapted by him to conform with the observed positions of the celestial objects when he wrote,[21] the age, when their positions would be conformable with the results of computations made as by him directed, is precisely the age of the author himself: and so far as Mr Bentley's calculations may be considered to approximate to the truth, the date of Brahmegupta's performance is determined with like approach to exactness, within a certain latitude however of uncertainty for allowance to be made on account of the inaccuracy of Hindu observations.

The translator has assigned on former occasions[22] the grounds upon which he sees reason to place the author's age, soon after the period, when the vernal equinox coincided with the beginning of the lunar mansion and zodiacal asterism *Aswini,* where the Hindu ecliptic now commences. He is supported in it by the sentiments of Bhascara and other Indian astronomers, who infer from Brahmegupta's doctrine concerning the solstitial points, of which he does not admit a periodical motion, that he lived when the equinoxes did not, sensibly to him, deviate from the beginning of *Aswini* and middle of *Chitra* on the Hindu sphere.[23] On these grounds it is maintained, that Brahmegupta is rightly placed in the sixth or beginning of the seventh century of the Christian era; as the subjoined calculations will more particularly show.[24] The age when Brahmegupta flourished, seems then, from the concurrence of all these arguments, to be satisfactorily settled as antecedent to the earliest dawn of the culture of sciences among the Arabs; and consequently establishes the fact, that the Hindus were in possession of algebra before it was known to the Arabians.

Brahmegupta's treatise, however, is not the earliest work known to have been written on the same subject by an Indian author. The most eminent scholiast of Bhascara[25] quotes a passage of Arya-bhatta specifying algebra under the designation of *Vija*, and making separate mention of *Cuttaca*, which more particularly intends a problem subservient to the general method of resolution of indeterminate problems of the first degree: he is understood by another of Bhascara's commentators[26] to be at the head of the elder writers, to whom the text then under consideration adverts, as having designated by the name of *Madhyamaharana* the resolution of affected quadratic equations by means of the completion of the square. It is to be presumed, therefore, that the treatise of Arya-bhatta then extant, did extend to quadratic equations in the determinate analysis; and to indeterminate problems of the first degree; if not to those of the second likewise, as most probably it did.

This ancient astronomer and algebraist was anterior to both Varahamihira and Brahmegupta; being repeatedly named by the latter; and the determination of the age when he flourished is particularly interesting, as his astronomical system, though on some points agreeing, essentially disagreed on others, with that which those authors have followed, and which the Hindu astronomers still maintain.[27]

He is considered by the commentators of the *Soorya siddhanta* and *Siromani*,[28] as the earliest of uninspired and mere human writers on the science of astronomy; as having introduced requisite corrections into the system of Parasara, from whom he took the numbers for the planetary mean motions; as having been followed in the tract of emendation, after a sufficient interval to make further correction requisite, by Durgasinha and Mihira; who were again succeeded after a further interval by Brahmegupta, son of Jishnu.[29]

In short, Arya-bhatta was founder of one of the sects of Indian astronomers, as Pulisa, an author likewise anterior to both Varahamihira and Brahmegupta, was of another: which were distinguished by names derived from the discriminative tenets respecting the commencement of planetary motions at sunrise according to the first, but at midnight according to the latter,[30] on the meridian of *Lanca*, at the beginning of the great astronomical cycle. A third sect began the astronomical day, as well as the great period, at noon.

His name accompanied the intimation which the Arab astronomers (under the Abbasside Khalifs, as it would appear) received, that three distinct astronomical systems were current among the Hindus of those days: and it is but slightly corrupted, certainly not at all disguised, in the Arabic representation of it *Arjabahar*, or rather *Arjabhar*.[31] The two other systems were, first, Brahmegupta's *Siddhanta*, which was the one they became best acquainted with, and to which they apply the denomination of the *sind-hind*; and second, that of *Arca* the sun, which they write *Arcand*, a corruption still prevalent in the vulgar *Hindi*.[32]

Arya-bhatta appears to have had more correct notions of the true explanation of celestial phenomena than Brahmegupta himself; who, in a few instances, correcting errors of his predecessor, but oftener deviating from that predecessor's juster views, has been followed by the herd of modern Hindu astronomers, in a system not improved, but deteriorated, since the time of the more ancient author.

Considering the proficiency of Arya-bhatta in astronomical science, and adverting to the fact of his having written upon Algebra, as well as to the circumstance of his being named by numerous writers as the founder of a sect, or author of a system in astronomy, and being quoted at the head of algebraists, when the commentators of extant treatises have occasion to mention early and original[33] writers on this branch of science, it is not necessary to seek further for a mathematician qualified to have been the great improver of the analytic art, and likely to have been the person, by whom it was carried to the pitch to which it is found to have attained among the Hindus, and at which it is observed to be nearly stationary through the long lapse of ages which have since passed: the later additions being few and unessential in the writings of Brahmegupta, of Bhascara, and of Jnyana Raja, though they lived at intervals of centuries from each other.

Arya-bhatta then being the earliest author known to have treated of Algebra among the Hindus, and being likely to be, if not the inventor, the improver, of that analysis, by whom too it was pushed nearly to the whole degree of excellence which it is found to have attained among them; it becomes in an especial manner interesting to investigate any discoverable trace in the absence of better and more direct evidence, which may tend to fix the date of his labours, or to indicate the time which elapsed between him and Brahmegupta, whose age is more accurately determined.[34]

Taking Arya-bhatta, for reasons given in the notes,[35] to have preceded Brahmegupta and Varahamihira by several centuries; and Brahmegupta to have flourished about twelve hundred years ago;[36] and Varahamihira, concerning whose works and age some further notices will be found in a subjoined note,[37] to have lived at the beginning of the sixth century after Christ,[38] it appears probable that this earliest of known Hindu algebraists wrote as far back as the fifth century of the Christian era; and, perhaps, in an earlier age. Hence it is concluded, that he is nearly as ancient as the Grecian algebraist Diophantus, supposed, on the authority of Abulfaraj,[39] to have flourished in the time of the emperor Julian, or about A.D. 360.

Admitting the Hindu and Alexandrian authors to be nearly equally ancient, it must be conceded in favour of the Indian algebraist, that he was more advanced in the science; since he appears to have been in possession of the resolution of equations involving several unknowns, which it is not clear, nor fairly presumable, that Diophantus knew; and a general method for indeterminate problems of at least the first degree, to a knowledge of which the Grecian algebraist had certainly not attained;

though he displays infinite sagacity and ingenuity in particular solutions; and though a certain routine is discernible in them.

A comparison of the Grecian, Hindu, and Arabian algebras, will more distinctly show, which of them had made the greatest progress at the earliest age of each, that can be now traced.

The notation or algorithm of Algebra is so essential to this art, as to deserve the first notice in a review of the Indian method of analysis, and a comparison of it with the Grecian and Arabian algebras. The Hindu algebraists use abbreviations and initials for symbols: they distinguish negative quantities by a dot;[40] but have not any mark, besides the absence of the negative sign, to discriminate a positive quantity. No marks or symbols indicating operations of addition, or multiplication, & c. are employed by them: nor any announcing equality[41] or relative magnitude (greater or less).[42] But a factum is denoted by the initial syllable of a word of that import,[43] subjoined to the terms which compose it, between which a dot is sometimes interposed. A fraction is indicated by placing the divisor under the dividend,[44] but without a line of separation. The two sides, of an equation are ordered in the same manner, one under the other,[45] and, this method of placing terms under each other being likewise practised upon other occasions,[46] the intent is in the instance to be collected from the recital of the steps, of the process in words at length, which always accompanies the algebraic process. The recital is also requisite to ascertain the precise intent of vertical lines interposed between the terms of a geometric progression, but used also upon other occasions to separate and discriminate quantities. The symbols of unknown quantity are not confined to a single one: but extend to ever so great a variety of denominations: and the characters used are initial syllables of the names of colours,[47] excepting the first, which is the initial of *yavat-tavat*, as much as; words of the same import with Bombelli's *tanto*; used by him for the same purpose. Colour therefore means unknown quantity, or the symbol of it: and the same *Sanscrit* word, *varna*, also signifying a literal character, letters are accordingly employed likewise as symbols; either taken from the alphabet;[48] or else initial syllables of words signifying the subjects of the problem; whether of a general nature,[49] or specially the names of geometric lines in algebraic demonstrations of geometric propositions or solution of geometric problems.[50] Symbols too are employed, not only for unknown quantities, of which the value is sought; but for variable quantities of which the value may be arbitrarily put, (*Vij* Ch.6, note on commencement of §153—156) and, especially in demonstrations, for both given and sought quantities. Initials of the terms for square and solid respectively denote those powers; and combined they indicate the higher. These are reckoned not by the sums of the powers; but by their products.[51] An initial syllable is in like manner used to mark a surd root.[52] The terms of a compound quantity are ordered according to the powers; and the absolute number invariably comes last. It also is distinguished by an initial syllable, as a discriminative token of known quantity.[53] Numeral coefficients are employed, inclusive of unity which is always noted, and comprehending fractions;[54] for the numeral divisor is generally so placed, rather than under the symbol of the unknown: and in like manner the negative dot is set over the numeral coefficient: and not over the literal character. The coefficients are placed after the symbol of the unknown quantity.[55] Equations are not ordered so as to put all the quantities positive; nor to give precedence to a positive term in a compound quantity: for the negative terms are retained, and even preferably put in the first place. In stating the two sides of an equation, the general, though not invariable, practice is, at least in the first instance, to repeat every term, which occurs in the one side, on the other: annexing nought for the coefficient, if a term of that particular denomination be there wanting.

If reference be made to the writings of Diophantus, and of the Arabian algebraists, and their early disciples in Europe, it will be found, that the notation, which has been here described, is essentially different from all theirs; much as they vary. Diophantus employs the inverted medial of *elleipsis,** defect or want (opposed to *huparxis*,* substance or abundance)[56] to indicate a negative quantity. He prefixes that mark Ψ to the quantity in question. He calls the unknown, *arithmos*;* representing it by the final S,* which he doubles for the plural; while the Arabian algebraists apply the equivalent word for number to the constant or known term; and the *Hindus*, on the other hand, refer the word for numerical character to the coefficient. He denotes the monad, or unit absolute, by μ°; and the linear quantity is called by him *arithmos*; and designated, like the unknown, by the final *sigma*. He marks the further powers by initials of words signifying them: δ^{v}, x^{v}, $\delta\delta^{e}$, δx^{v}, xx^{v} & c. for *dynamis*, power (meaning the square); *cubos*, cube; *dynamo-dynamis*, biquadrate, & c. But he reckons the higher by the sums, not the products, of the lower. Thus the sixth power is with him the *cubo-cubos*, which the *Hindus* designate as the quadratecube, (cube of the square, or square of the cube).

The Arabian Algebraists are still more sparing of symbols, or rather entirely destitute of them.[57] They have none, whether arbitrary or abbreviated, either for quantities known or unknown, positive or negative, or for the steps and operations of an algebraic process: but express every thing by words, and phrases, at full length. Their European scholars introduced a few and very few abbreviations of names: c^{o}, c^{e}, c^{u}, for the three first powers; c^{o}, q^{2}, for the first and second unknown quantities; p, m, for plus and minus; and R* for the note of radicality; occur in the first printed work which is that of Paciolo.[58] Leonardo Bonacci of *Pisa*, the earliest scholar of the Arabians,[59] is said by Targioni Tozzetti to have used the small letters of the alphabet to denote quantities.[60] But Leonardo only does so because he represents quantities by straight lines, and designates those lines by letters, in elucidation of his Algebraic solutions of problems.[61]

The Arabians termed the unknown (and they wrought but on one) *shai* thing. It is translated by Leonardo of *Pisa* and his disciples, by the correspondent Latin word *res* and Italian *cosa*; whence *Regola de la Cosa*, and Rule of *Coss*, with *Cossike* practice and *Cossike* number of our older authors,[62] for Algebra or Speculative practice, as Paciolo[63] denominates the analytic art; and *Cossic* number, in writers of a somewhat later date, for the root of an equation.

The *Arabs* termed the square of the unknown *mál*, possession or wealth; translated by the Latin *census* and the Italian *censo*; as terms of the same import: for it is in the acceptation of amount of property or estate[64] that *census* was here used by Leonardo.

The cube was by the Arabs termed *Cab*, a die or cube; and they combined these terms *mal* and *cab* for compound names of the more elevated powers; in the manner of Diophantus by the sums of the powers; and not like the *Hindus* by their products. Such indeed, is their method in the modern elementary works: but it is not clear, that the same mode was observed by their earlier writers; for their Italian scholars denominated the biquadrate and higher powers Relato primo, secundo, tertio, & c.

Positive they call *zaid,* additional; and negative, *nakis,* deficient: and, as before observed, they have no discriminative marks for either of them.

The operation of *restoring* negative quantities, if any there be, to the positive form, which is an essential step with them, is termed *jebr*, or with the article *Aljebr*, the mending or restoration. That of *comparing*, the terms and taking like from like, which is the next material step in the process of resolution, is called by them *mukabalah* comparison. Hence the name of *Tarik aljebr wa almukabala*, ‘the method of restoration and comparison’, which obtained among the Arabs for this branch of the Analytic art; and hence our name of Algebra, from Leonardo of *Pisa*’s exact version of the Arabic title. *Firistakhrajul majhulat* *ba taríк aljebr wa almukabalah*,[65] De solutione quarundam quæstionum secundum modum *Algebrae* et *Almuchabalae.*[66]

The two steps or operations, which have thus given name to the method of analysis, are precisely what is enjoined without distinctive appellations of them, in the introduction of the arithmetics of Diophantus, where he directs, that, if the quantities be positive on both sides, like are to be taken from like until one species be equal to one species; but, if on either side or on both, any species be negative, the negative species must be added to both sides, so that they become positive on both sides of the equation: after which like are again to be taken from like until one species remain on each side.[67]

The Hindu Algebra, not requiring the terms of the equation to be all exhibited in the form of positive quantity, does not direct the preliminary step of *restoring* negative quantity to the affirmative state: but proceeds at once to the operation of equal subtraction (*samasodhana*) for the difference of like terms which is the process denominated by the Arabian Algebraists comparison (*mukabalah*). On that point, therefore, the Arabian Algebra has more affinity to the Grecian than to the Indian analysis.

As to the progress which the Hindus had made in the analytic art, it will be seen, that they possessed well the arithmetic of surd roots;[68] that they were aware of the infinite quotient resulting from the division of finite quantity by cipher;[69] that they knew the general resolution of equations of the second degree; and had touched upon those of higher denomination; resolving them in the simplest cases, and in those in which the solution happens to be practicable by the method which serves for quadratics;[70] that they had attained a general solution of indeterminate problems of the first degree;[71] that they had arrived at a method for deriving a multitude of solutions of answers to problems of the second degree from a single answer found tentatively;[72] which is as near an approach to a general solution of such problems, as was made until the days of La Grange, who first demonstrated that the problem, on which the solutions of all questions of this nature depend, is always resolvable in whole numbers.[73] The *Hindus* had likewise attempted problems of this higher order by the application of the method which suffices for those of the first degree;[74] with indeed very scanty success, as might be expected.

They not only applied algebra both to astronomy[75] and to geometry;[76] but conversely applied geometry likewise to the demonstration of Algebraic rules.[77] In short, they cultivated Algebra much more, and with greater success, than geometry; as is evident from the comparatively low state of their knowledge in the one,[78] and the high pitch of their attainments in the other: and they cultivated it for the sake of astronomy, as they did this chiefly for astrological purposes. The examples in the earliest algebraic treatise extant (Brahmegupta's) are mostly astronomical: and here the solution of indeterminate problems is sometimes of real and practical use. The instances in the later treatise of Algebra by Bhascara are more various: many of them geometric; but one astronomical; the rest numeral: among which a great number of indeterminate; and of these some, though not the greatest part, resembling the questions which chiefly engage the attention of Diophantus. But the general character of the Diophantine problems and of the Hindu unlimited ones is by no means alike: and several in the style of Diophantine are noticed by Bhascara in his arithmetical, instead of his algebraic, treatise.[79]

To pursue this summary comparison further, Diophantus appears to have been acquainted with the direct resolution of affected quadratic equations; but less familiar with the management of them, he seldom touches on it. Chiefly busied with indeterminate problems of the first degree, he yet seems to have possessed no general rule for their solution. His elementary instructions for the preparation of equations are succinct.[80] His notation, as before observed, scanty and inconvenient. In the whole science, he is very far behind, the Hindu writers: not withstanding the infinite ingenuity, by which he makes up for the want of rule: and although presented to us under the disadvantage or mutilation; if it be, indeed, certain that the text of only six, or at most seven, of thirteen books which his introduction announces, has been preserved.[81] It is sufficiently clear from what does remain, that the lost part could not have exhibited a much higher degree of attainment in the art. It is presumable, that so much as we possess of his work, is a fair specimen of the progress which he and the Greeks before him (for he is hardly to be considered as the inventor, since he seems to treat the art as already known) had made in his time.

The points, in which the Hindu Algebra appears particularly distinguished from the Greek, are, besides a better and more comprehensive algorithm,—*1st*, The management of equations involving more than one unknown term. (This adds to the two classes noticed by the Arabs, namely simple and compound, two, or rather three, other classes of equation) *2nd*, The resolution of equations of a higher order, in which, if they achieved little, they had, at least, the merit of the attempt, and anticipated a modern discovery in the solution of biquadratics. *3rd*, General methods for the solution of indeterminate problems of 1st and 2nd degrees, in which they went far, indeed, beyond Diophantus, and anticipated discoveries of modern Algebraists. *4th*, Application of Algebra to astronomical investigation and geometrical demonstration: in which also they hit upon some matters which have been reinvented in later times.

This brings us to the examination of some of their anticipations of modern discoveries. The reader's notice will be here drawn to three instances in particular.

The first is the demonstration of the noted proposition of Pythagoras, concerning the square of the base of a rectangular triangle, equal to the squares of the two legs containing a rightangle. The demonstration is given two ways in Bhascara's Algebra, (*Vija-ganita* § 146). The first of them is the same which is delivered by Wallis in his treatise on angular sections, (Ch.6.) and, as far as appears, then given for the first time.[82]

On the subject of demonstrations, it is to be remarked that the Hindu mathematicians proved propositions both algebraically, and geometrically: as is particularly noticed by Bhascara himself, towards the close of his Algebra, where he gives both modes of proof of a remarkable method for the solution of indeterminate problems, which involve a factum of two unknown quantities. The rule, which he demonstrates, is of great antiquity in Hindu Algebra: being found in the works of his predecessor Brahmegupta, and being there a quotation from a more ancient treatise; for it is injudiciously censured, and a less satisfactory method by unrestricted arbitrary assumption given in its place. Bhascara has retained both.

The next instance, which will be here noticed, is the general solution of indeterminate problems of the first degree. It was first given among moderns by Bachet de Meziriac in 1624.[83] Having shown how the solution of equations of the form $ax\text{-}by = c$ is reduced to $ax\text{-}by = \pm 1$, he proceeds to resolve this equation: and prescribes the same operation on a and b as to find the greatest common divisor. He names the residues c, d, e, f, & c. and the last remainder is necessarily unity: a and b being prime to each other. By retracing the steps from $e \pm 1$ or $f \pm 1$ (according as the number of remainders is even or odd)

$$e \pm 1 = \varepsilon, \frac{\varepsilon d \pm 1}{e} = \delta, \frac{\delta c \mp 1}{d} = \gamma, \frac{\gamma b \pm 1}{c} = \beta, \frac{\beta a \mp 1}{b} = a$$

$$or\ f \pm 1 = \zeta, \frac{\zeta e \mp 1}{f} = \varepsilon, \frac{\varepsilon d \pm 1\delta}{e}, \&c.$$

The last numbers ß and ∝ will be the smallest values of x and y. It is observed, that, if a and b be not prime to each other, the equation cannot subsist in whole numbers unless c be divisible by the greatest common measure of a and b.

Here we have precisely the method of the Hindu algebraists, who have not failed, likewise, to make the last cited observation. See *Brahm.* Algebra, section 1 and *Bhasc. Lil.* Ch.12. *Vij.* Ch.2. It is so prominent in the Indian Algebra as to give name to the oldest treatise on it extant; and to constitute a distinct head in the enumeration of the different branches of mathematical knowledge in a passage cited from a still more ancient author. See *Lil.* § 248.

Confining the comparison of Hindu and modern Algebras to conspicuous instances, the next for notice is that of the solution of indeterminate problems of the 2nd degree: for which a general method is given by Brahmegupta, besides rules for subordinate cases: and two general methods (one of them the same with Brahmegupta's) besides special cases subservient however to the universal solution of problems of this nature; and, to obtain whole numbers in all circumstances, a combination of the method for problems of the first degree with that for those of the second, employing them alternately, or, as the Hindu algebraist terms it, proceeding in a circle.

Bhascara's second method (*Vij.* § 80-81) for a solution of the problem on which all indeterminate ones of this degree depend, is exactly the same, which Lord Brouncker devised to answer a question proposed by way of challenge by Fermat in 1657. The thing required was a general rule for finding the innumerable square numbers, which multiplied by a proposed (non-quadrate) number, and then assuming an unit, will make a square. Lord Brouncker's rule, putting n for any given number, r^2 for any square taken at pleasure, and d for difference between n and $r^2 (r^2 \sim n)$ was $\frac{4r^2}{d^2} = (\frac{2r}{d} \text{x} \frac{2r}{d})$ the square required. In the Hindu rule, using the same symbols, $\frac{2r}{d}$ is the square root required.[84] But neither Brouncker, nor Wallis, who himself contrived another method, nor Fermat, by whom the question was proposed, but whose mode of solution was never made known by him, (probably because he had not found anything better than Wallis and

Brouncker discovered)[85] nor Frenicle, who treated the subject without, however, adding to what had been done by Wallis and Brouncker,[86] appear to have been aware of the importance of the problem and its universal use: a discovery, which, among the moderns, was reserved for Euler in the middle of the last century. To him, among the moderns, we owe the remark, which the Hindus had made more than a thousand years before,[87] that the problem was requisite to find all the possible solutions of equations of this sort. La Grange takes credit for having further advanced the progress of this branch of the indeterminate analysis, so lately as 1767;[88] and his complete solution of equations of the 2nd degree appeared no earlier than 1769.[89]

It has been pretended, that traces of the art are to be discovered in the writings of the Grecian geometers, and particularly in the five first propositions of Euclid's thirteenth book; whether, as Wallis conjectures, what we there have be the work of Theon or some other ancient scholiast, rather than of Euclid himself: Also examples of analytic investigation in Pappus;[91] and indications of a method somewhat of a like nature with algebra, or at least the effects of it, in the works of Archimedes and Apollonius; though they are supposed to have very studiously concealed this their art of invention.[92]

This proceeds on the ground of considering Analysis and Algebra, as interchangeable terms; and applying to Algebra Euclid's or Theon's definition of Analysis, 'a taking of that as granted, which is sought; and thence by consequences arriving at what is confessedly true.'[93]

Undoubtedly they possessed a geometrical analysis; hints of traces of which exist in the writings of more than one Greek mathematician, and especially in those of Archimedes. But this is very different from the Algebraic Calculus. The resemblance extends, at most, to the method of inversion; which both Hindus and Arabians consider to be entirely distinct from their respective Algebras; and which the former, therefore, join with their arithmetic and mensuration.[94]

In a very general sense, the analytic art, as Hindu writers observe, is merely sagacity exercised; and is independent of symbols, which do not constitute the art. In a more restricted sense, according to them, it is calculation attended with the manifestation of its principles: and, as they further intimate a method aided by devices, among which symbols and literal signs are conspicuous.[95] Defined, as analysis by an illustrious modern mathematician,[96] 'a method of resolving mathematical problems by reducing them to equations,' it assuredly is not to be found in the works of any Grecian writer extant, besides Diophantus.

In his treatise the rudiments of Algebra are clearly contained. He delivers in a succinct manner the Algorithm of affirmative and negative quantities; teaches to form an equation; to transpose the negative terms; and to bring out a final simple equation comprising a single term of each species known and unknown.

Admitting on the ground of the mention of a mathematician of his name, whose works were commented by Hypatia about the beginning of the fifth century;[97] and on the authority of the Arabic annals of an Armenian Christian;[98] which make him contemporary with Julian; that he lived towards the middle of the fourth century of the Christian era; or, to speak with precision, about the year 360;[99] the Greeks will appear to have possessed in the fourth century so much of Algebra, as is to be effected by dexterous application of the resolution of equations of the first degree, and even the second, to limited problems; and to indeterminate also, without, however, having attained a general solution of problems of this latter class.

The Arabs acquired Algebra extending to simple and compound (meaning quadratic) equations; but it was confined, so far as appears, to limited problems of those degrees: and they possessed it so early as the close of the eighth century, or commencement of the ninth. Treatises were at that period written in the Arabic language on the Algebraic Analysis, by two distinguished mathematicians who flourished under the Abbasside Almamun: and the more ancient of the two, Muhammed ben Musa *Al Khuwarezmi*, is recognised among the Arabians as the first who made Algebra known to them. He is the same, who abridged, for the gratification of Almamun, an astronomical work taken from the Indian system in the preceding age, under Almansur. He framed tables likewise, grounded on those of the Hindus; which he professed to correct. And he studied and communicated to his countrymen the Indian compendious method of computation; that is, their arithmetic, and, as is to be inferred, their analytic calculus also.[100]

The Hindus in the fifth century, perhaps earlier,[101] were in possession of Algebra extending to the general solution of both determinate and indeterminate problems of the 1st and 2nd degrees: and subsequently advanced to the special solution of biquadratics wanting the second term; and of cubics in very restricted and easy cases.

Priority seems then decisive in favour of both Greeks and Hindus against any pretensions on the part of the Arabians, who in fact, however, prefer none, as inventors of Algebra. They were avowed borrowers in science: and, by their own unvaried acknowledgement, from the Hindus they learnt the science of numbers. That they also received the Hindu Algebra, is much more probable, than that the same mathematician who studied the Indian arithmetic and taught it to his Arabian brethren, should have hit upon Algebra unaided by any hint or suggestion of the Indian analysis.

The Arabs became acquainted with the Indian astronomy and numerical science, before they had any knowledge of the writings of the Grecian astronomers and mathematicians: and it was not until after more than one century, and nearly two, that they had the benefit of an interpretation of Diophantus, whether version or paraphrase, executed by Muhammed Abulwafa *Al Buzjani*; who added, in a separate form, demonstrations of the propositions contained in Diophantus; and who was likewise author of Commentaries on the Algebraic treatises of the

Khuwarezmite Muhammed ben Musa, and of another Algebraist of less note and later date, Abi Yahya, whose lectures he had personally attended.[102] Any inference to be drawn from their knowledge and study of the *Arithmetics* of Diophantus and their seeming adoption of his preparation of equations in their own Algebra, or at least the close resemblance of both on this point, is of no avail against the direct evidence, with which we are furnished by them, of previous instruction in Algebra and the publication of a treatise on the art, by an author conversant with the Indian science of computation in all its branches.

But the age of the earliest known Hindu writer on Algebra, not being with certainty carried to a period anterior, or even quite equal to that in which Diophantus is on probable grounds placed, the argument of priority, so far as investigation has yet proceeded, is in favour of Grecian invention. The Hindus, however, had certainly made distinguished progress in the science, so early as the century immediately following that in which the Grecian taught the rudiments of it. The Hindus had the benefit of a good arithmetical notation: the Greeks, the disadvantage of a bad one. Nearly allied as algebra is to arithmetic, the invention of the algebraic calculus was more easy and natural where arithmetic was best handled. No such marked identity of the Hindu and Diophantine systems is observed, as to demonstrate communication. They are sufficiently distinct to justify the presumption, that both might be invented independently of each other.

If, however, it be insisted, that a hint or suggestion, the seed of their knowledge, may have reached the Hindu mathematicians immediately from the Greeks of Alexandria, or mediately through those of Bactria, it must at the same time be confessed, that a slender germ grew and fructified rapidly, and soon attained an approved state of maturity in Indian soil.

More will not be here contended for: since it is not impossible, that the hint of the one analysis may have been actually received by the mathematicians of the other nation; nor unlikely, considering the arguments which may be brought for a probable communication on the subject of astrology; and adverting to the intimate connection between this and the pure mathematics, through the medium of astronomy.

The Hindus had undoubtedly made some progress at an early period in the astronomy cultivated by them for the regulation of time. Their calendar, both civil and religious, was governed chiefly, not exclusively, by the moon and sun: and the motions of these luminaries were carefully observed by them: and with such success, that their determination of the moon's synodical revolution, which was what they were principally concerned with, is a much more correct one than the Greeks ever achieved.[103] They had a division of the ecliptic into twenty-seven and twenty-eight parts, suggested evidently by the moon's period in days; and seemingly their own: it was certainly borrowed by the Arabians.[104] Being led to the observation of the fixed stars, they obtained a knowledge of the positions of the most remarkable; and noticed, for religious purposes, and from superstitious notions, the heliacal rising, with other phenomena of a few. The adoration of the sun, of the planets, and of the stars, in common with the worship of the elements, held a principal place in their religious observances, enjoined by the *Vedas*:[105] and they were led consequently by piety to watch the heavenly bodies. They were particularly conversant with the most splendid of the primary planets; the period of Jupiter being introduced by them, in conjunction with those of the sun and moon, into the regulation of their calendar, sacred and civil, in the form of the celebrated cycle of sixty years, common to them and to the Chaldeans, and still retained by them. From that cycle they advanced by progressive stages, as the Chaldeans likewise did, to larger periods; at first by combining that with a number specifically suggested by other, or more correctly determined, revolutions of the heavenly bodies; and afterwards, by merely augmenting the places of figures for greater scope, (preferring this to the more exact method of combining periods of the planets by an algebraic process; which they likewise investigated)[106] until they arrived finally at the unwieldy cycles named *Mahayugas* and *Calpas*. But it was for the sake of astrology, that they pushed their cultivation of astronomy, especially that of the minor planets, to the length alluded to. Now divination, by the relative position of the planets, seems to have been, in part at least, of a foreign growth, and comparatively recent introduction, among the Hindus. The belief in the influence of the planets and stars, upon human affairs, is with them, indeed, remotely ancient; and was a natural consequence of their creed, which made the sun a divine being, and the planets gods. But the notion, that the tendency of that supposed influence, or the manner in which it will be exerted, may be foreseen by man, and the effect to be produced by it foretold, through a knowledge of the position of the planets at a particular moment, is no necessary result of that creed: for it takes from beings believed divine, free-agency in other respects, as in their visible movements.

Whatever may have been the period when the notion first obtained, that foreknowledge of events on earth might be gained by observations of planets and stars, and by astronomical computation; or wherever that fancy took its rise; certain it is, that the Hindus have received and welcomed communications from other nations on topics of astrology; and although they had astrological divinations of their own as early as the days of Parasara and Garga, centuries before the Christian era, there are yet grounds to presume that communications subsequently passed to them on the like subject, either from the Greeks, or from the same common source (perhaps that of the Chaldeans) whence the Greeks derived the grosser superstitions engrafted on their own genuine and ancient astrology, which was meteorological.

This opinion is not now suggested for the first time. Former occasions have been taken of intimating the same sentiment on this point:[107] and it has been strengthened by further consideration of the subject. As the question is closely connected with the topics of this dissertation, reasons for this opinion will be stated in the subjoined note.[108]

Joining this indication to that of the division of the zodiac into twelve signs, represented by the same figures of animals, and named by words of the same import with the zodiacal signs of the Greeks; and taking into consideration the analogy, though not identity, of the Ptolemaic system, or rather that of Hipparchus, and the Indian one of eccentric deferents and epicycles, which in both serve to account for the irregularities of the planets, or at least to compute them, no doubt can be entertained that the Hindus received hints from the astronomical schools of the Greeks.

It must then be admitted to be at least possible, if not probable, in the absence of direct evidence and positive proof, that the imperfect algebra of the Greeks, which had advanced in their hands no further than the solution of equations, involving one unknown term, as it is taught by Diophantus, was made known to the Hindus by their Grecian instructors in improved astronomy. But, by the ingenuity of the Hindu scholars, the hint was rendered fruitful, and the algebraic method was soon ripened from that slender beginning to the advanced state of a well arranged science, as it was taught by Arya-bhatta, and as it is found in treatises compiled by Brahmegupta and Bhascara, both of which versions are here presented to the public.

Note

1. *Goladhyaya*; or lecture on the sphere. c.II.§ 56. *As. Res.* vol. 12. p.214.

2. *As. Res. Ibid.*

3. Though the matter be introductory, the preliminary treatises on arithmetic and algebra may have been added subsequently, as is hinted by one of the commentators of the astronomical part. (*Vartic.*) The order there intimated places them after the computation of planets, but before the treatise on spherics; which contains the date.

4. Note A. (Notes A to O referred to in some of the subsequent footnotes are not reproduced here: *Editor*)

5. For example, by Suryadasa, under *Lilavati*, § 74; and still more frequently by Ranganatha.

6. *Vija-Ganita*, § 218.

7. *Ibid.* § 131.

8. *Ibid.* § 142.

9. *Vija-Ganita* Ch.5. Note of Suryadasa. Also *Vija-Ganita* § 174; and *Lil.* § 246 ad finem.

10. For example, under *Lil.* Ch.11.

11. Note G.

12. Note B.

13. *Vasana-bhashya* by Chaturveda Prithudaca Swami, son of Madhusudana, on the *Brahma-siddhanta*; (or sometimes *Bramhasphuta-siddhanta*).

14. They often quote from the *Brahma-siddhanta* after premising a reference to Brahmegupta.

15. Note C.

16. Note D.

17. *As. Res.* 2. 225.

18. *Ibid.* 9. 242.

19. Note E.

20. *As. Res.* 6. 586.

21. *Supra.*

22. *As. Res.* 9. 329.

23. *Ibid.* 12. p. 215.

24. Note F.

25. Ganesa, a distinguished mathematician and astronomer.

26. Sur. on *Vija-ganita* § 128.

27. Note G.

28. *Nrisinha* on *Sur.* Ganesa pref. to *Grah. lagh.*

29. *As. Res.* 2. 235, 242, and 244; and Note H.

30. Brahmegupta, Ch.11. The names are *Audayaca* from *Udaya* rising; and *Ardharatrica* from *Ardharatri*, midnight. The third school is noticed by Bhattotpala the scholiast of Varahamihira, under the denomination of *Madhyandinas*, as alleging the commencement of the astronomical period at noon: (from *Madhyandina*, mid-day.)

31. The *Sanscrit t*, it is to be remembered, is the character of a peculiar sound often mistaken for *r*, and which the Arabs were likely so to write, rather than with a *te* or with a *tau*. The Hindi *t* is generally written by the English in India with an *r*. Example: *Ber (vata)*, the Indian fig. vulg. Banian tree.

32. See notes I, K, and N.

33. Surya-dasa on *Vija-Ganita*, Ch.5.

34. Note I.

35. (Not indicated in original; probably as in 34: *Editor*)

36. See before and note F.

37. Note K.

38. See before and note E.

39. Pococke's edition and translation, p.89.

40. *Vija-ganita* § 4.

41. The sign of equality was first used by Robert Recorde, because, as he says, no two things can be more equal than a pair of parallels, or *gemowe* lines of one length. *Hutton*.

42. The signs of relative magnitude were first introduced into European algebra by Harriot.

43. *Vija-ganita* § 21.

44. *Lil.* § 33.

45. *Vija-ganita* and *Brahm.* 18, *passim.*

46. *Vija-ganita* § 55.

47. *Vija-ganita* § 17. *Brahm.* c. 18, § 2.

48. *Vija-ganita* Ch.6.

49. *Vija-ganita* § 111.

50. *Vija-ganita* § 146.

51. *Lil.* § 26.

52. *Vija-ganita* § 29.

53. *Vija-ganita* § 17.

54. Stevinus in like manner included fractions in coefficients.

55. Vieta did so likewise.

*Transliterated from the original Greek letters: *Editor*.

56. A word of nearly the same import with the *Sanscrit dhana*, wealth, used by Hindu algebraists for the same signification.

56a. Def. 9. (Reference not legible in text*: Editor*)

57. *As. Res.* 12. 183.

58. Or Pacioli, Paciuolo,—LI, & c. For the name is variously written by Italian authors.

59. See Note L.

60. *Viaggi*, 2nd Edit. vol.2, p.62.

61. Cossali, Origine dell'Algebra, i.

62. Robert Recorde's Whetstone of Witte.

63. Secondo noi detta Pratica Speculativa. *Summa* 8.1.

64. *Census*, quicquid fortunarum quis habet. *Steph. Thes.*

65. *Khulasatulhisab* c. 8. *Calcutta.*

66. *Liber abbaci*, 9.15.3. M.S. in Magliab. Libr.

67. Def. 11.

68. *Brahm.* 18 § 27-29. *Vija-ganita* § 29-52

69. *Lil* § 45. *Vija-ganita* § 15-16 and § 135.

70. *Vija-ganita* § 129. and § 137—138

71. *Brahm.* 18. § 3-18 *Vija-ganita* 53-73. *Lil.* § 248—265.

72. *Brahm.* 18. § 29-49. *Vija-ganita* § 75-99.

73. Mem. of Acad. of Turin: and of Berlin.

74. *Vija-ganita* § 206—207.

75. *Brahm.* 18. passim. *Vija-ganita.*

76. *Vija-ganita* § 117—127. § 146-152.

77. *Vija-ganita* § 212—214.

78. *Brahm.* 12. § 21; corrected however in *Lil.* § 169—170.

79. *Lil.* § 59—61, where it appears, however, that preceding writers had treated the question algebraically. See likewise § 139—146.

80. Def. 11.

81. Note M.

82. (See following page)

82. He designates the sides C.D. Base B. Segments x, . Then

$$\left.\begin{array}{l} B : C : : C : \chi \\ B : D : : D : \delta \end{array}\right\} \text{and therefore} \left\{\begin{array}{l} C^2 = B\chi \\ D^2 = B\delta \end{array}\right.$$

Therefore,

The Indian demonstration, with the same symbols, is

$$\left.\begin{array}{l} B : C : : C : \chi \\ B : D : : D : \delta \end{array}\right\} \text{Therefore} \left\{\begin{array}{l} \chi = \dfrac{C^2}{B} \\ \delta = \dfrac{D^2}{B} \end{array}\right.$$

Therefore $B = \chi + \delta = \dfrac{C^2}{B} + \dfrac{D^2}{B}$ and $B^2 = C^2 + D^2$.

83. Problémes plaisans et délectables qui se font par les nombres. 2nd Edit. (1624). La Grange's additions to Euler's Algebra, ij. 382. (Edit. 1807)

84. *Vija-ganita* § 80-81.

85. Wallis, Alg. c. 98.

86. *Ibid.*

87. *Bhascara Vij.* § 173, and § 207. See likewise *Brahm.* Alg. Sec. 7.

88. *Mem. Acad. de Berlin*, vol.24.

89. See French translation of Euler's Algebra, Additions, p.286. And Legendre Theorie des Nombres 1. § 6. No.36.

90. Wallis, Algebra, c. 2.

91. *Ibid.* and Preface.

92. *Ibid.* and Nunéz Algebra 114.

93. Wallis, following Vieta's version, Alg. c. I.

94. *Lil.* 3. 1. § 47. *Khulasat. Hisab.* c. 5.

95. *Vija-ganita* § 110, 174, 215, 224.

96. D'Alembert.

97. Suidas, in voce *Hypatia.*

98. Gregory Abulfaraj. Ex iis etiam {nempe philosophis qui prope tempora Juliani floruerunt} Diophantus, cujus liber, quem Algebram vocant, celebris est, in quem si immiserit se Lector, oceanum hoc in genere reperiet.—*Pococke.*

99. Julian was emperor from 360 to 363. See Note M.

100. Note N.

101. See note I

102. See note N.

103. *As. Res.* 2 and 12.

104. *As. Res.* 9, Essay vi.

105. *As. Res.* 8.

106. Brahmegupta, Algebra.

107. *As. Res.* 12.

108. Note O.

PART II

TECHNOLOGY

VII

OPERATION OF INOCULATION OF THE SMALLPOX AS PERFORMED IN BENGALL

(From Ro. Coult to Dr Oliver Coult in 'An account of the diseases of Bengall' (Calcutta, dated February 10, 1731).)

Here follows one account of the operation of inoculation of the smallpox as performed here in Bengall taken from the concurring accounts of several Bhamans and physicians of this part of India.

The operation of inoculation called by the natives *tikah* has been known in the kingdom of Bengall as near as I can learn, about 150 years and according to the Bhamanian records was first performed by one Dununtary, a physician of Champanager, a small town by the side of the Ganges about half way to Cossimbazar whose memory is now holden in great esteem as being thought the author of this operation, which secret, say they, he had immediately of God in a dream.

Their method of performing this operation is by taking a little of the pus (when the smallpox are come to maturity and are of a good kind) and dipping these in the point of a pretty large sharp needle. Therewith make severall punctures in the hollow under the deltoid muscle or sometimes in the forehead, after which they cover the part with a little paste made of boiled rice.

When they want the operation of the inoculated matter to be quick they give the patient a small bolus made of a little of the pus, and boiled rice immediately after the operation which is repeated the two following days at noon.

The place where the punctures were made commonly festures and comes to a small supporation, and if not the operation has no effect and the person is still liable to have the smallpox but on the contrary if the punctures do supporate and no feaver or eruption insues, then they are no longer subject to the infection.

The punctures blacken and dry up with the other pustules.

The feaver insues later or sooner, according to the age and strength of the person inoculated, but commonly the third or fourth days. They keep the patient under the coolest regimen they can think off before the feaver comes on and frequently use cold bathing.

If the eruption is suppressed they also use frequent cold bathing. At the same time they give warm medicine inwardly, but if they prove of the confluent kind, they use no cold bathing, but (keep) the patient very cooll and give coolling medicine.

I cannot say any thing of the success of this operation or of their method of cure in this disease, but I intend to inform myself perfectly when the time of this distemper returns which is in April and May.

VII

AN ACCOUNT OF THE MANNER OF INOCULATING FOR THE SMALLPOX IN THE EAST INDIES

(By J.Z. Holwell, F.R.S. addressed to the President and Members of the College of Physicians in London. (A.D. 1767))

On perusing lately some tracts upon the subject of inoculation, I determined to put together a few notes relative to the manner of inoculation, practised, time out of mind by *the Bramins of Indostan*; to this I was chiefly instigated, by considering the great benefit that may arise to mankind from a knowledge of this foreign method, which so remarkably tends to support the practice now generally followed with such marvellous success.

By Dr Schultz's account of inoculation, page 65, note (9), it should seem, that the world has been already obliged with a performance of the kind which I have now undertaken, by a Dutch author a friend of Mr Chais; but as this is all I know of that work, it shall not discourage my proceeding with my own, the more specially as that performance is in a foreign language, and may not much benefit my country.

As many years have elapsed, since a theme of this nature has employed my thoughts and attention; I will hope for every favourable indulgence from the candor of that learned and respectable Body, to whose judgment I most readily submit the following history and observations.

It has been lately remarked by a learned and judicious ornament of the College of Physicians, 'That the Art of Medicine has, in several instances, been greatly indebted to accident; and that some of its most valuable improvements have been received from the hands of ignorance and barbarism; a truth, remarkably exemplified in the practice of inoculation of the small pox.' However just *in general* this learned gentleman's remark may be, he will as to his *particular reference*, be surprised to find, that nearly the same salutary method, now so happily pursued in England, (howsoever it has been seemingly blundered upon) has the sanction of remotest antiquity; but indeed with some variations, that will rather illustrate the propriety of the present practice, and promote the obvious very laudable intention, with which that gentleman published his late essay on this interesting subject.

The general state of this distemper in the provinces of Bengall (to which these observations are limited) is such that for five and sometimes six years together, it passes in a manner unnoticed, from the few that are attacked with it; for the complexion of it in these years is generally so benign as to cause very little alarm; and notwithstanding the multitudes that are every year inoculated in the usual season, it adds no malignity to the disease taken in the natural way, nor spreads the infection, as is commonly imagined in Europe. Every seventh year, with scarcely any exception, the smallpox rages epidemically in these provinces, during the months of March, April and May; and sometimes until the annual returning rains, about the middle of June, put a stop to its fury. On these periodical returns (to four of which I have been a witness) the disease proves universally of the most malignant confluent kind from which few either of the natives or Europeans escaped, that took the distemper in the natural way, commonly dying on the first, second, or third day of the eruption; and yet, inoculation in the East, has *natural fears* and *superstitious prejudices* to encounter, as well as in the West. The usual resource of the Europeans is to fly from the settlements, and retire into the country before the return of the smallpox season.

It is singularly worth remarking, that there hardly ever was an instance of a native of the Island of St. Helena, man or woman, that was seized with this distemper in the natural way (when resident in Bengall) who escaped with life; although it is a known fact that the disease never yet got footing upon that Island. Clearly to account for this, is not an easy matter; I will venture, however, a few conjectures on the occasion. These people rarely migrate from the Island before they arrive at years of maturity; the basis of their diet there, from their infancy, is a root called *yam*, of a *skranshee* kind, a term they use to express its acrid, unwholesome qualities, which frequently subjects them to epidemic and dangerous dysenteries and sometimes epidemic putrid sore throats. The blood thus charged, must necessarily constitute a most unlucky habit of body to combat with any acute inflammatory disease whatsoever, but more especially of the kind under consideration (so frequently attended with a high degree of putrefaction) always fatal to these people, even in those seasons when the disease is mild and favourable to others: But indeed it is a general remark, that a St Helenian rarely escapes when seized with the smallpox in whatsoever part of the Globe he happens to reside. The same has been observed of the African Coffries, although I know not what cause to ascribe it to, unless we suppose one similar to that above mentioned, to wit, some fundamental aggravating principle in their chief diet. Be this as it may, that these two portions of the human species seem peculiarly marked as victims to this disease, is a fact indisputable, let the cause be what it will.

Having thus far premised touching the general state of this distemper in the provinces of Bengall, (which I believe is nearly applicable to every other part of the Empire) I will only add a few words respecting the duration of it in Indostan, and then hasten to the principal intention of this short essay.

The learned Doctor Friend in his History of Physic from the time of Galen, has this remarkable passage: ‘By the earliest account we have of the smallpox, we find it first appeared in Egypt in the time of Omar, successor to Mahomet; though no doubt, since the Greeks knew nothing of it, the Arabians brought it from their own country; and might derive it originally from some of the more distant regions of the East.’ The sagacity of this conclusion, later times and discoveries has fully verified, at the period in which the *Aughtorrah Bhade* scriptures of the Gentoos were promulgated, (according to the Bramins three thousand three hundred and sixty-six years ago) this disease must then have been of some standing, as those scriptures institute a form of divine worship, with *Poojahs* or offerings, to a female divinity, styled by the common people *Gootee ka Tagooran* (the goddess of spots), whose aid and patronage are invoked during the continuance of the smallpox season, also in the measles, and every cutaneous eruption that is in the smallest degree epidemical. Due weight being given to this circumstance, the long duration of the disease in Indostan will manifestly appear; and we may add to the sagacious conjecture just quoted, that not only the Arabians, but the Egyptians also, by their early commerce with India through the Red Sea and Gulf of Mocha, most certainly derived originally the small pox (and probably the measles likewise) from that country, where those diseases have reigned from the earliest known times.

Inoculation is performed in Indostan by a particular tribe of Bramins, who are delegated annually for this service from the different Colleges of Bindoobund, Eleabas, Benares, & c. over all the distant provinces; dividing themselves into small parties, of three or four each, they plan their travelling circuits in such wise as to arrive at the places of their respective destination some weeks before the usual return of the disease; they arrive commonly in the Bengall provinces early in February, although they some years do not begin to inoculate before March, deferring it until they consider the state of the season, and acquire information of the state of the distemper.

The year in Bengall can properly be divided into three seasons only, of four months each; from the middle of June to the middle of October is the rainy season; from the middle of October to the middle of February is the cold season, which never rises to a degree of freezing; the whole globe does not yield a more desirable or delightful climate than Bengall during these four months, but the freedom of living, which the Europeans fall into at this season, sow the seeds of those diseases which spring up in all the succeeding months of the year. From the middle of February to the middle of June is the hot, windy, dry season; during which no rain falls but what comes in storms of fierce winds and tremendous thunder and lightning, called North Westers, the quarter they always rise from; and the provinces, particularly Bengall, is more or less healthy, in proportion to the number of these storms; when in this season the air is frequently agitated and refreshed with these North Westers, accompanied with rain, (for they are often dry) and the inhabitants do not expose themselves to the intense sun and violent hot winds that blow in March, April and May, it is generally found to be the most healthy of the year; otherwise (as in the year 1744, when we had no rain from the twentieth of October to the twentieth of June) this season produces high inflammatory disorders of the liver, breast, pleura, and intestines, with dysenteries, and a deplorable species of the smallpox.

From the middle of July (the second month of the rainy season) there is little or no wind, a stagnation of air follows, and during the remainder of this month, and the months of August and September, the atmosphere is loaded with suffocating heat and moisture, the parents of putrefaction; and nervous putrid fevers (approaching sometimes to pestilential) take the lead, and mark the dangerous season; from these fevers the natives frequently recover, but the Europeans seldom, especially if they in the preceding May and June indulged too freely in those two bewitching delicacies, Mangoes and Mango Fish, indiscriminately with the free use of flesh and wine; for these (all together) load the whole habit with impurities, and never fail of yielding death a plentiful harvest, in the three last months of this putrid season: If any are seized with the smallpox in these months, it is ever of the most malignant kind, and usually fatal. It will not, I hope, be deemed a useless digression, if I bestow a few remarks on the nature of this Bengall fever.

A day or two before the seizure, the patient finds his appetite fall off, feels an unaccountable lassitude, and failure in the natural moisture of the mouth, is low spirited without any apparent cause, and cannot sleep as usual; but having no acute complaint whatsoever, nor preternatural heat, that should indicate a fever, he attributes the whole to the heat of the season, is satisfied with fasting and confinement to his house, or goes abroad amongst his friends to ‘shake it off’, as the common phrase is; but on the third day, finding every one of these symptoms increase, he begins to think something is really the matter with him, and the physician is called in: thus the only period is lost wherein art might be of any use; for in the course of eighteen years practice I never knew an instance of recovery from this genuine fever, where the first three days had elapsed without assistance and the patient in this case died on the fifth or seventh day. In some, this fever is attended with a full equal, undisturbed pulse, but obviously greatly *oppressed*; in others with a low and *depressed* one, but equal and undisturbed also, and yet both required the same treatment. Newcomers in the profession, have been often fatally misled by the full pulse, which they thought indicated the loss of blood; they followed the suggestion, the pulse suddenly fell, and when that happens from this cause, the art of man can never raise it again, the patient dies on the fifth or seventh day; and the consequence was exactly the same, if nature, being overloaded, attempted to free herself of part of the burden by a natural haemorrhage, or by the intestines, on the second or third day, (which I have often seen) they proved equally fatal as the lancet. Until the close of the sixth day the skin and urine preserved a natural state; but if at this period of the fever the skin suddenly acquired an intense heat, and the urine grew crude and limpid, it was a sure presage of death on the seventh. The natural crisis of this fever, when attacked in the very beginning, and treated judiciously, was regularly on the eleventh day, and appeared in a multitude of small boils, chiefly upon the head or in small watery bladders thrown out upon the surface of the skin, but in the greatest abundance on the breast, neck, throat, and forehead; both of these critical appearances are constantly preceded, on the tenth day, by a copious sediment and separation in the urine. If by any inadvertent exposure to the cold air, these critical eruptions were struck in, the repelled matter instantly fell upon the brain, and convulsions, and death followed in a few hours, and small purple spots remained in the places of the eruptions. Such is the *genuine putrid nervous fever of Bengall*, which never gave way properly to any treatment but that of blisters applied universally, supported by the strongest alexipharmics; sometimes I have seen the crisis (by unskilful management) spun out to the twenty-first day, but it has been ever imperfect, and the patient is harassed with intermittents or diarrhoeas, and commonly dies in the beginning of the cold season; but if he is of a strong constitution, he lingers on, in a dying way, until the month of February, which usually gives some turn in his favour, but his health is hardly ever re-established before the salutary *mango season*, which fruit, eaten with *milk*, proves an effectual and never-failing restorative. But to resume our subject.

The inhabitants of Bengall, knowing the usual time when the inoculating Bramins annually return, observe strictly the regimen enjoined, whether they determine to be inoculated or not; this preparation consists only in abstaining for a month from fish, milk, and ghee (a kind of butter made generally of buffalo's milk); the prohibition of fish respects only the native Portuguese and Mahomedans, who abound in every province of the empire.

When the Bramins begin to inoculate, they pass from house to house and operate at the door, refusing to inoculate any who have not, on a strict scrutiny, duly observed the preparatory course enjoined them. It is no uncommon thing for them to ask the parents how many pocks they choose their children should have: Vanity, we should think, urged a question on a matter seemingly so uncertain in the issue; but true it is, that they hardly ever exceed, or are deficient, in the number required.

They inoculate indifferently on any part, but if left to their choice, they prefer the outside of the arm, midway between the wrist and the elbow, for the males; and the same between the elbow and the shoulder for the females. Previous to the operation the Operator takes a piece of cloth in his hand, (which becomes his perquisite if the family is opulent) and with it gives a dry friction upon the part intended for inoculation, for the space of eight or ten minutes, then with a small instrument he wounds, by many slight touches, about the compass of a silver groat,[1] just making the smallest appearance of blood, then opening a linen double rag (which he always keeps in a cloth round his waist) takes from thence a small pledget of cotton charged with the variolous matter, which he moistens with two or three drops of the *Ganges* Water, an applies it to the wound, fixing it on with a slight bandage, and ordering it to remain on for six hours without being moved, then the bandage to be taken off, and the pledget to remain until it falls off itself; sometimes (but rarely) he squeezes a drop from the pledget, upon the part, before he applies it; from the time he begins the dry friction, to tying the knot of the bandage, he never ceases reciting some portions of the worship appointed, by the *Aughtorrah Bhade*, to be paid to the female divinity before mentioned, nor quits the most solemn countenance all the while. The cotton, which he preserves in a double callico rag, is saturated with matter from the inoculated pustules of the preceding year, for they never inoculate with fresh matter, nor with matter from the disease caught in the natural way, however distinct and mild the species. He then proceeds to give instructions for the treatment of the patient through the course of the process, which are most religiously observed; these are as follows:

He extends the prohibition of fish, milk and ghee, for one month from the day of inoculation; early on the morning succeeding the operation, four collans (an earthen pot containing about two gallons) of cold water are ordered to be thrown over the patient, from the head downwards, and to be repeated every morning and evening until the fever comes on, (which usually is about the close of the sixth day from the inoculation) then to desist until the appearance of the eruptions, (which commonly happens at the close of the third complete day from the commencement of the fever) and then to pursue the cold bathing as before, through the course of the disease, and until the scabs of the pustules drop off. They are ordered to open all the pustules with a fine sharp pointed thorn, as soon as they begin to change their colour, and whilst the matter continues in a fluid state. Confinement to the house is absolutely forbid, and the inoculated are ordered to be exposed to every air that blows; and the utmost indulgence they are allowed when the fever comes on, is to be laid on a mat at the door; but, in fact, the eruptive fever is generally so inconsiderable and trifling, as very seldom to require this indulgence. Their regimen is ordered to consist of all the refrigerating things the climate and season produces, as plantains, sugar-canes, water melons, rice, gruel made of white poppy-seeds, and cold water, or thin rice gruel for their ordinary drink. These instructions being given, and an injunction laid on the patients to make a thanksgiving *Poojah*, or offering, to the goddess on their recovery, the Operator takes his fee, which from the poor is a *pund of cowries*, equal to about a penny sterling, and goes on to another door, down one side of the street and up on the other, and is thus employed from morning until night, inoculating sometimes eight or ten in a house. The regimen they order, when they are called to attend the disease taken in the natural way, is uniformly the same. There usually begins to be a discharge from the scarification a day before the eruption, which continues through the disease, and sometimes after the scabs of the pock fall off, and a few pustules generally appear round the edge of the wound; when these two circumstances appear only, without a single eruption on any other part of the body, the patient is deemed as secure from future infection, as if the eruption had been general.

When the before recited treatment of the inoculated is strictly followed, it is next to a miracle to hear, that one in a million fails of receiving the infection, or of one that miscarries under it; of the multitudes I have seen inoculated in that country, the number of pustules have been seldom less than fifty, and hardly ever exceeded two hundred. Since, therefore, this practice of the East has been followed without variation, and with uniform success from the remotest known times, it is but justice to conclude, it must have been originally founded on the basis of rational principles and experiment.

Although I was very early prejudiced in preference of the cool regimen and free admission of air, in the treatment of this disease, yet, on my arrival in Bengall, I thought the practice of the Bramins carried *both* to a bold, rash, and dangerous extreme; but a few years experience gave me full conviction of the propriety of their method; this influenced my practice, and the success was adequate; and I will venture to say, that every gentleman in the profession who did not adopt the same mode, (making a necessary distinction and allowance between the constitutions of the natives and Europeans) have lost many a patient, which might otherwise have been saved; as I could prove in many instances, where I have been called in too late to be of any assistance. But to form a judgment of the propriety of this eastern practice with more precision, it will be best to analyse it, from the period of the enjoined preparation, to the end of the process; as thereby an opportunity presents itself of displaying the principles on which the Bramins act, and by which they justify their singular method of practice.

It has been already said, that the preparative course consists only in abstaining from fish, milk and ghee; respecting the first, it is known to be a viscid and inflammatory diet, tending to foul and obstruct the cutaneous glands and excretory ducts, and to create in the stomach and first passages a tough, slimy phlegm, highly injurious to the human constitution; as these are the generally supposed qualities of this diet, it seems forbidden upon the justest grounds.

Touching milk, which is the basis (next to rice) of all the natives food, I confess I was surprised to find it one of the forbidden articles, until I was made acquainted with their reasoning on the subject. They say that milk becomes highly nutritious, not only from its natural qualities, but principally from its ready admission into the blood, and quick assimilation with it; and that it consequently is a warm heating diet, and must have a remote tendency to inflammation, whenever the blood is thrown into any preternatural ferment, and therefore, that milk is a food highly improper, at a season when the preternatural fermentation that produces the smallpox ought to be feared, and guarded against by every person who knows himself liable to the disease, or determined to prepare himself for receiving it, either from nature or art. Upon this principle and reasoning it is, that their women, during the course of their periodical visitations, are strictly forbid, and religiously abstain from, the use of milk, lest it should, upon any accidental cold, dispose the uterus to inflammation and ulceration; and from the same apprehension, the use of it is as strictly prohibited during the flow of the lochia, and is avoided as so much poison; our European women, resident in India, have adopted the same precaution from experience of the effect, and will not, on any consideration, at those times, mix the smallest quantity with their tea, a lesson they derive from their midwives, who are all natives, and generally are instructed in their calling by the Bramins, and other practitioners in physic.

Concerning the third interdicted article, they allege, that under *that* is implied a prohibition of all fat and oily substances, as their qualities are nearly similar with those of fish, and similar in their effects of fouling the first passages in a high degree above any other ailment that is taken into them; that they soon acquire an acrimony in the course of digestion, and convey the same into the blood and juices; these premises being granted, which I think can hardly be denied, there appears sufficient cause for prohibiting the use of the whole tribe; the more especially, as ghee and oil are the essential ingredients used in cooking their vegetable diet.

Thus far the system of practice pursued by the Bramins will, I imagine, appear rational enough, and well founded; but they have other reasons for particularly prohibiting the use of these three articles, which to some may appear purely speculative, if not chimerical. They lay it down as a *principle*, that the *immediate* (or instant) cause of the smallpox exists in the mortal part of every human and *animal* form;[2] that the *mediate* (or second) *acting* cause, which stirs up the *first*, and throws it into a state of fermentation, is multitudes of *imperceptible animalculae* floating in the atmosphere; that these are the cause of all epidemical diseases, but more particularly of the small pox; that they return at particular seasons in greater or lesser numbers; that these bodies, imperceptible as they are to the human organs of vision, imprison the most malignant tribes of the *fallen angelic spirits*: That these animalculae touch and adhere to every thing, in greater or lesser proportions, according to the nature of the surfaces which they encounter; that they pass and repass in and out of the bodies of all animals in the act of respiration, without injury to themselves, or the bodies they pass through; that such is not the case with those that are taken in with the food, which, by mastication, and the digestive faculties of the stomach and intestines, are crushed and assimilated with the chyle, and conveyed into the blood, where, in a certain time, their malignant juices excite a fermentation peculiar to the *immediate* (or *instant*) cause, which ends in an eruption on the skin. That they adhere more closely, and in greater numbers, to glutinous, fat, and oily substances, by which they are in a manner taken prisoners; that *fish*, *milk*, and *ghee*, have these qualities in a more eminent and dangerous degree, and attach the animalculae, and convey them in greater quantities into the blood, and for these reasons, added to those before assigned, they are forbid to be taken in food during the preparative course. They add, that the small pox is more or less epidemical, more mild or malignant, in proportion as the air is charged with these animalculae, and the quantity of them received with the food. That though we all receive, with our ailment, a portion of them, yet it is not always sufficient in quantity to raise this peculiar ferment, and yet may be equal to setting the seeds of other diseases in motion; hence the reason why any epidemical disorder seldom appears alone. That when once this *peculiar* ferment, which produces the smallpox, is raised in the blood, the *immediate (instant) cause* of the disease is totally expelled in the eruptions, or by other channels; and hence it is, that the blood is not susceptible of a second fermentation of the same kind. That inoculating for this disease was originally hinted by the *divinity* presiding over the *immediate (instant) cause*, the thought being much above the reach of human wisdom and foresight. That the great and obvious benefit accruing from it, consists in this, that the fermentation being excited by the action of a small portion of matter (similar to the *immediate* cause) which *had already passed through* a state of fermentation, the effects must be moderate and benign; whereas the fermentation raised by the malignant juices of the animalculae received into the blood with the ailment, gives necessarily additional force and strength to the first efficient cause of the disease.

That noxious animalculae, floating in the atmosphere, are the cause of all pestilential, and other epidemical disorders, is a doctrine the Bramins are not singular in; however, some of the conclusions drawn from it, are purely their own. A speculative genius may amuse itself by assigning this or that efficient cause, or first principle of this disease; but the best conjecture which the wisdom of man can frame, will appear vague and uncertain; nor is it of much moment, in the present case, to puzzle the imagination, by a minute enquiry into the essence of a cause hidden from us, when the effects are so visible, and chiefly call for our regard: but if we must assign *a cause*, why every part of the globe, *at particular seasons*, is more liable to peculiar malignant epidemical diseases, than *at others*, (which experience manifests) I see no one that so much wears the complexion of probability, as that of pestilent animalculae, driven by stated winds, or generated on the spot by water and air in a state of stagnation, (and consequently in a state of putrefaction favourable to their propagation) and received into the habit with our food and respiration. We yearly see, in a greater or lesser degree, the baneful effects of these insects in blights, although at their first seizure of a plant they are invisible, even with the assistance of the best glasses; and I hope I shall not be thought to refine too much on the argument, if I give it as my opinion, that epidemical blights, and epidemical diseases of one kind or other, may be observed to go often hand in hand with each other, from the same identical cause. But to proceed in our analysis.

The mode by which the Eastern inoculators convey the variolous taint into the blood, has nothing uncommon in it, unless we except the preceding friction upon the part intended for inoculation, and moistening the saturated pledget, before the application of it; for this practice they allege the following reasons; that by *friction* the circulation in the small sanguinary vessels is accelerated, and the matter being diluted by a small portion of *Ganges* Water, is, from both causes, more readily and eagerly received, and the operation at the same time sanctified. The friction and dilution of the matter, has certainly the sanction of very good common sense; and the *Ganges* Water, I doubt not, may have as much efficacy as any other *holy water* whatsoever. This last circumstance, however, keeps up the piety and solemnity with which the operation is conducted from the beginning to the end of it; it tends also to give confidence to the patient, and so far is very laudable. The reasons they assign for giving the preference to matter of the *preceding* year, are singular and judicious; they urge, it is more certain in its effects; that necessity first pointed out the fact, (the variolous matter some years not being procurable) and experience confirmed it: they add, that when the matter is effectually secured from the air, it undergoes at the return of the season an *imperceptible fermentation*, which gives fresh vigour to its action. It is no uncommon thing to inoculate with matter four or five years old, but they generally prefer that of a year old, conceiving that the fermentation which constitutes its superiority over fresh matter, is yearly lessened, and consequently the essential spirit of action weakened, after the first year.

The next article of the Eastern practice, which offers in the course of our discussion, is their sluicing their patients over head and ears, morning and evening, with cold water, until the fever comes on; in which the inoculating Bramins are, beyond controversy, singular: but before we can penetrate the grounds and reasons for this practice, it becomes necessary to bestow a few words on the usual manner of cold bathing in the East, when medically applied, which is simply this; the water is taken up over night, in three, four, or five vessels, before described, (according to the strength of the patient) and left in the open air, to receive the dews of the night, which gives it an intense coldness; then in the morning, before the sun rises, the water is poured without intermission, by two servants, over the body, from the distance of six or twelve inches above the head. This mode of cold bathing has been adopted from the Eastern professors of physic, by all the European practitioners, and by constant experience found abundantly more efficacious than that by immersion, in all cases where that very capital remedy was indicated; notwithstanding it has been ever the received opinion, that the success of cold bathing, is as much, or rather more, owing to the weight and pressure of the circumambient body of water, than *the shock*. The remarkable superior efficacy of this Eastern method of cold bathing, can only be accounted for, from *the shock* being infinitely greater, and of longer continuance, than that received by immersion; which is a fact indisputable, as will be acknowledged by every one who goes through a course of both methods; the severity of the one being nothing comparable to the other: this I assert from my own personal feelings; and I never had a patient that did not aver the same, who had undergone both trials: indeed, the shock of this Eastern method is so great, that, in many cases, when the subject was deeply exhausted and relaxed, I found it absolutely necessary to begin the course only with a *quart* of water.

If the known effects of cold bathing are attended to, and its sovereign virtues duly considered, in the very different circumstances of palsies, rheumatism, general relaxation of the solids, and particular relaxation of the stomach and intestines, we shall not be long at a loss to account for this part of the Eastern practice in the course of inoculation: They allege in defence of it, that by the sudden shock of the cold water, and consequent increased motion of the blood, all offensive principles are forcibly driven from the heart, brain, and other interior parts of the body, towards the extremities and surface, and at the same time the intended fermentation is thereby more speedily and certainly promoted; (hence it probably is, that the fever generally commences so early as about the close of the sixth day). When the fever appears, they desist from the use of the cold water, because when the fermentation is once begun, the blood should not, they say, receive any additional commotion until the eruption appears, when they again resume the cold water, and continue it to the end of the disease; asserting, that the use of it alone, by the daily fresh *impetus* it gives to the blood, enables it utterly to expel and drive out the remainder of the *immediate* cause of the disease into the pustules. I have been myself an eyewitness to many instances of its marvelous effect, where the pustules have sunk, and the patient appeared in imminent danger, but almost instantly restored by the application of three or four collans of cold water, which never fails of filling the pock, as it were by enchantment; and so great is the stress laid by the Eastern practitioners on this preparative (for as the three interdicted articles in food is preparative to the inoculation, so this may be deemed preparative to the eruption) that when they are called in, and find, upon enquiry, that circumstance (and opening the pustules) has not been attended to, they refuse any further attendance.

The next and last article of the Eastern practice, which falls under our consideration is that just above mentioned, viz. the opening of the pustules whilst the matter continues in a fluid state. That a circumstance so important, so self-evidently rational and essential, should have been so long unthought of, appears most wonderful! And if my memory fails me not, Helvetius is the only writer upon the subject of the smallpox, that hinted it in practice before Doctor Tissot; this accurate and benevolent physician has enforced it with such strength of judgment and argument, that he leaves little room (except facts) to add to his pathetic persuasive; in this he is supported by his learned and elegant commentator and translator Doctor Kirkpatrick, (pp.226 and 227) and I am not without hopes it will, contrary to Doctor

Tissot's expectation, 'become a general practice'; the more especially, when it is found to have invariable success, and venerable antiquity, for its sanction.

So great is the dependence which the Eastern practitioners have on opening the pustules, in every malignant kind of the disease, that where the fluid state of the matter has been suffered to elapse without being evacuated, they pronounce the issue fatal, and it generally proves so; they order it in every kind, even the most distinct; for although in these it should seem scarcely necessary, yet they conceive it effectually prevents inflammation and weakness of the eyes, biles, and other eruptions and disorders, which so commonly succeed the disease, however benign; in very critical cases, they will not trust the operation of opening the pustules to the nurses or relations, but engage in it themselves, with amazing patience and solicitude; and I have frequently known them thus employed for many hours together; and when it has been zealously persevered in, I hardly ever knew it fail, of either entirely preventing, the *second fever*, or mitigating it in such sort, as to render it of no consequence; in various instances, which I have been a witness to, in my own, and others practice, I have seen the pustules in the *contiguous* kind, upon being successively opened, fill again to the fourth and fifth, and in the *confluent*, to the sixth, seventh, and eighth time; in the very distinct sort they will not fill again more than once or twice, and sometimes not at all, which was a plain indication, that the whole virus of the disease was expelled in the first eruption.

The Eastern practitioners, with great modesty, arraign the European practice of phlebotomy and cathartics in any stage of the disease, but more particularly when designed to prevent, or mitigate the second fever; alleging, that the *first* weakens the natural powers, and that the *latter* counteracts the regular course of *nature*, which in this disease invariably tends to throw out the offending cause *upon the skin*; that she often proves unequal to the entire expulsion of the enemy, in which case, her wise purposes are to be assisted by art, in that track, which she herself points out, and not by a diversion of the usual crisis into another channel; that this assistance can only be attempted with propriety, by emptying the pustules, as thereby fresh room is given in them for the reception of the circulating matter still remaining in the blood, and which could not be contained in the first eruption; by which means every end and purpose of averting, or subduing the *second fever* is obtained, with a moral certainty; whilst phlebotomy and cathartics, administered with this view, are both irrational and precarious; as being opposite to the constant operation of nature in her management of this dreadful disease.

It remains only that I add a word or two upon the Eastern manner of opening the pustules, which (as before mentioned) is directed to be done with a very fine sharp pointed thorn: Experience has established the use of this natural instrument in preference to either the scissors, lancet, or needle; the practitioners perforate the most prominent part of the pustule, and with the sides of the thorn press out the pus; and having opened about a dozen, they absorb the matter with a calico rag, dipped in warm water and milk; and proceed thus until the whole are discharged; the orifice made by the thorn is so extremely small, that it closes immediately after the matter is pressed out, so that there is no admission of the external air into the pustule, which would suddenly contract the mouths of the excretory vessels, and consequently the further secretion of the variolous matter from the blood would be thereby obstructed; for this consideration, the method recommended by Doctor Tissot, of clipping the pustules with sharp pointed scissors, is certainly liable to objection, as the aperture would be too large; when in the true confluent kind, no distinct pustules present, they perforate the most prominent and promising parts, in many places, at the distance of a tenth of an inch, usually beginning at the extremities; and I have often seen the pustules in the *contiguous*, and the perforated parts in the *confluent* kind, fill again before the operation has been half over; yet they do not repeat the opening until a few hours elapse, conceiving it proper that the matter should receive some degree of concoction in the pustules before it is again discharged.

If the foregoing essay on the Eastern mode of treating the smallpox, throws any new and beneficial lights upon this cruel and destructive disease, or leads to support and confirm the present successful and happy method of inoculation, in such wise as to introduce, into *regular and universal practice, the cool regimen and free admission of air*, (the contrary having proved the bane of millions) I shall, in either case, think the small time and trouble bestowed in putting these facts together most amply recompensed.

Notes

1. The instrument they make use of, is of iron, about four inches and a half long, and of the size of a large crow quill, the middle is twisted, and the one end is steeled and flatted about an inch from the extremity, and the eighth of an inch broad; this extremity is brought to a very keen edge, and two sharp corners; the other end of the instrument is an earpicker, and the instrument is precisely the same as the Barbers of Indostan use to cut the nails, and depurate the ears of their customers,

(for in that country, we are above performing either of these operations ourselves).

The Operator of inoculation holds the instrument as we hold a pen, and with dexterous expedition gives about fifteen or sixteen minute scarifications (within the compass above mentioned) with one of the sharp corners of the instrument, and to these various little wounds, I believe may be ascribed the discharge which almost constantly flows from the part in the progress of the disease. I cannot help thinking that too much has been said (pro and con) about nothing, respecting the different methods preferred by different practitioners of performing the operation; provided the matter is thrown into the blood, it is certainly, a consideration of most trivial import by what means it is effected; if any claims a preference, I should conclude it should be that method which bids fairest for securing a plentiful discharge from the ulcer.

2. In an epidemic season of the confluent smallpox, turkeys, Chittygong fowls, Madrass capons, and other poultry, are carried off by the disease in great numbers; and have the symptoms usually accompanying every stage of the distemper. I had a favourite parrot that died of it in the year 1744; in him I had a fair opportunity of observing the regular progress of the disorder; he sickened, and had an ardent fever full two days before the eruption, and died on the seventh day of the eruption; on opening him, we found his throat, stomach, and whole channel of the first passages, lined as thick with the pustules as the surface of his body, where, for the most part, they rose contiguous, but in other places they ran together.

IX

THE METHOD OF MAKING THE BEST MORTAR AT MADRASS IN EAST INDIA

(By Hon'ble Isaac Pyke, Esq; Governor of St. Helena (Published 1732).)

Take fifteen bushels of fresh, pit-sand, well sifted; add thereto fifteen bushels of stone-lime: Let it be moistened or slack'd with water in the common manner, and so laid two or three Days together.

Then dissolve 20 lb of *jaggery*, which is coarse sugar (or thick molasses) in water, and sprinkling this liquor over the mortar, beat it up together till all be well mixed and incorporated, and then let it lie by in a heap.

Then boil a peck of *gramm* (which is a sort of grain like a *tare*, or between that and a *pea*) to a jelly, and strain it off through a coarse canvass, and preserve the liquor that comes from it.

Take also a peck of *myrabolans*, and boil them likewise to a jelly, preserving that water also as the other; and if you have a vessel large enough, you may put these three waters together; that is, the *jaggery*-water, the *gram*-water, and the *myrabolan*. The *Indians* usually put a small quantity of fine lime therein, to keep their labourers from drinking of it.

The mortar beat up, and when too dry, sprinkled with this liquor, proves extraordinarily good for laying brick or stone therewith; keeping some of the liquor always at hand for the workman to wet his bricks therewith; and if this liquor prove too thick, dilute it with fresh water.

Observe also, that the mortar here is not only to be well beaten and mixed together, but also laid very well, and every brick, or piece of brick, slushed in with the mortar, and every cranny filled up, yet not in thick joints, like the common *English* mortar; and also over every course of bricks, some to be thrown on very thin: And where the work hath stood, though but for a breakfast or a dining-time, before you begin again wet it well with this liquor with a ladle, and then lay on your fresh mortar; for this mortar, notwithstanding its being thus wetted, dries much sooner than one not used to it would conceive, but especially in hot weather.

For some very strong work, the same mortar above is improved as follows:

Take coarse tow and twist it loosely into bands as thick as a man's finger (in *England* ox-hair is used instead of this tow) then cut it into pieces of about an inch long and untwist it so as to lie loose; then strew it lightly over the other mortar which is at the same time to be kept turning over, and so this stuff to be beat into it, keeping labourers continually beating in a trough, and mixing it till it be well incorporated with all the parts of the mortar. And whereas it will be subject to dry very fast, it must be frequently softened with some of the aforesaid liquor of *jaggery, gram,* and *myrabolans*, and some fresh water; and when it is so moistened, and beat, it will mix well, and with this they build (though it be not usual to build common house-walls thus) when the work is intended to be very strong; as for instance, *Madrass* Church Steeple, that was building when I was last there; and also for some ornaments, as columns, good arched work, or imagery set up in gardens, it is thus made.

Though for common buildings about Madrass, where the rainy season holds not above three months in the year, and sometimes less, they usually lay all the common brick-work in a loamy clay, and plaster it over on both sides with this mortar, which is yet further to be improved. Thus far for building-mortar.

Having your mortar thus prepared, as is before described, you must separate some of it, and to every half bushel, you are to take the white of five or six eggs, and four ounces of *ghee* (or ordinary unsalted butter) and a pint of butter-milk, beaten all well together: Mix a little of your mortar with this, until all your *ghee*, whites of eggs, and butter-milk be soaked up; then soften the rest well with plain fresh water, and so mix all together, and let it be ground, a trowel full at a time, on a stone with a stone-roller, in the same manner that chocolate is usually made, or ground in *England*; and let it stand by in a trough for use. And when you use it, in case it be too dry, moisten it with some water, or the before mentioned liquor. This is the second coat of plastering.

Note, when your first coat of plastering is laid on, let it be well rubbed on with a hardening trowel, or with a smooth brick, and strewed with a gritty sand, moistened, as occasion requires, with water, or the before mentioned liquor, and then well hardened on again; which, when half dry, take the last mentioned composition for your fine plastering, and when it is almost dry, lay on your whitening varnish; but if your work should be quite dry, then your *chinam* liquor must be washed over the work with a brush.

The best sort of whitening varnish is thus made. Take one gallon of *toddy*, a pint of butter-milk, and so much fine *chinam*, or lime, as shall be proper to colour it; add thereunto some of the *chinam* liquor before mentioned, wash it gently over therewith; and when it is quite dried in, do the same again. And a plaster thus made is more durable than some soft stone, and holds the weather better in *India*, than any of the bricks they make there.

In some of the fine *Chinam* that is to endure the weather, and where it is likely to be subject to much rain, they put *gingerly oil* (*Oleum Sesami.*) instead of *ghee*, and also in some they boil the bark of the *mango* tree, and other barks of astringent natures, and *aloes*, which grow here in great plenty by the sea-shore; but to all of the fine *chinam*, that is for outside plastering, they put butter-milk, which is here called *toyre*. And for inside work they use glue made very thin and weak, instead of size, for white-washing; and sometimes they add a little gum to it.

N.B. Whereas sundry ingredients here mentioned are not to be had in *England*, it may not be amiss to substitute something more plentiful here, which I imagine to be of the same nature.

As to all the astringent barks, I take oaken-bark to be as good as any.

Instead of *aloes*, either *turpentine*, or the bark and branches of the *sloe* tree. Though *turpentine* be not so strong, yet if used in greater quantity, may serve the same purpose.

But there is a sort of *Aloes Hepatica*, often very cheap. Instead of *myrabolans* some juice of *aloes (*Sloes.*)*; also instead of *jaggery*, coarse sugar, or *molasses*, will do; instead of *toddy*, which is a sort of *palm* wine, the liquor from the *birch* tree comes near to it.

Note, that in *China*, and some other parts, they temper their mortar with blood of any sorts of cattle; but the ingredients before mentioned are said to be as binding, and do full as well, and does not make the mortar of so dark a colour as blood will do.

The plastering above described, is thought in *India* vastly to exceed any sort of *stucco* work, or plaster of *Paris*; and I have seen a room done with this sort of terrass-mortar that has fully come up to the best sort of wainscot-work, in smoothness and in beauty.

X

THE PROCESS OF MAKING ICE IN THE EAST INDIES

(By Sir Robert Barker. F.R.S. (Published 1775).)

The process of making ice in the East Indies having become a subject of speculation, I beg permission to present you with the method by which it was performed at Allahabad, Mootegil, and Calcutta, in the East Indies, lying between 25½ and 23½ degrees on North latitude. At the latter place I have never heard of any persons having discovered natural ice in the pools or cisterns, or in any waters collected in the roads; nor has the thermometer been remarked to descend to the freezing point; and at the former very few only have discovered ice, and that but seldom: But in the process of making ice at these places it was usual to collect a quantity every morning, before sunrise (except in some particular kinds of weather, which I shall specify in the sequel), for near three months in the year: viz from December till February.

The ice-maker belonging to me at Allahabad (at which place I principally attended to this enquiry) made a sufficient quantity in the winter for the supply of the table during the summer season. The methods he pursued were as follows: on a large open plain, three or four excavations were made, each about thirty feet square and two deep; the bottoms of which were strewed about eight inches or a foot thick with sugar-cane, or the stems of the large Indian corn dried. Upon this bed were placed in rows, near to each other, a number of small, shallow, earthen pans, for containing the water intended to be frozen. These are unglazed, scarce a quarter of an inch thick, about an inch and a quarter in depth, and made of an earth so porous, that it was visible, from the exterior part of the pans, the water had penetrated the whole substance. Towards the dusk of the evening, they were filled with soft water, which had been boiled, and then left in the afore-related situation. The ice-makers attended the pits usually before the sun was above the horizon, and collected in baskets what was frozen, by pouring the whole contents of the pans into them, and thereby retaining the ice, which was daily conveyed to the grand receptacle or place of preservation, prepared generally on some high dry situation, by sinking a pit of fourteen or fifteen feet deep, lined first with straw, and then with a coarse kind of blanketing, where it is beat down with rammers, till at length its own accumulated cold again freezes and forms one solid mass. The mouth of the pit is well secured from the exterior air with straw and blankets, in the manner of the lining, and a thatched roof is thrown over the whole. It is here necessary to remark, that the quantity of ice depends materially on the weather; and consequently, it has sometimes happened, that no congelation took place. At others, perhaps, half the quantity will be frozen; and I have often seen the whole contents formed into a perfect cake of ice: the lighter the atmosphere, and the more clear and serene the weather, the more favourable for congelation, as a frequent change of winds and clouds are certain preventives. For I have frequently remarked, that after a very sharp cold night, to the feel of the human body, scarce any ice has been formed; when at other times the night has been calm and serene, and sensibly warmer, the contents of the pans will be frozen through. The strongest proof of the influence of the weather appears by the water in one pit being more congealed than the same preparation for freezing will be in other situations, a mile or more distant.

To reason physically upon this process of making ice, it may be said, that had the thermometer been suspended in the air, free from every other body capable of communicating heat, in some parts of the night during the cold months of December, January, and February, the quicksilver might have descended to the freezing point, and that water, being artfully placed in a similar situation, contained in thin porous pans, and supported by a substance little capable of communicating heat from the earth, might also freeze, and continue in a state of congelation till the heat of the morning came on. I say this may be possible; but at the same time I must beg leave to observe, that, during my residence in that quarter of the globe, I never saw any natural ice. I cannot declare that the thermometer has not descended to the freezing point during the night, because I never made the necessary observations; but the water in every other situation, excepting in the pans, has not appeared to be in a freezing state. The climate may probably contribute in some measure to facilitate the congelation of water, when placed in a situation free from the heat of the earth, since those nights in which the greatest quantity of ice has been produced, were, as I before observed, perfectly serene, the atmosphere sharp and thin, with very little dew after midnight. Many gentlemen, now in England, have made the same remarks, in their frequent visits with me to the ice-pits. The spongy nature of the sugar-canes, or stems of the Indian corn, appears well calculated to give a passage under the pans to the cold air; which, acting on the exterior parts of the vessels, may carry off by evaporation a proportion of the heat. The porous substance of the vessels seems equally well qualified for the admission of the cold air internally; and their situation being full a foot beneath the plane of the ground, prevents the surface of the water from being ruffled by any small current of air, and thereby preserves the congealed particles from disunion. Boiling the water is esteemed a necessary preparative to this method of congelation; but how far this may be consonant with philosophical reasoning, I will not presume to determine.

From these circumstances it appears, that water, by being placed in a situation free from receiving heat from other bodies, and exposed in large surfaces to the air, may be brought to freeze when the temperature of the atmosphere is some degrees above the freezing point on the scale of *Fahrenheit's* thermometer; and by being collected and amassed into a large body, is thus preserved, and rendered fit for freezing other fluids, during the severe heats of the summer season. In effecting which there is also an established mode of proceeding; the sherbets, creams, or whatever other fluids are intended to be frozen, are confined in thin silver cups of a conical form, containing about a pint, with their covers well luted on with paste, and placed in a large vessel filled with ice, salt-petre, and common salt, of the two last an equal quantity, and a little water to dissolve the ice and combine the whole. This composition presently freezes the contents of the cups to the same consistency of our ice creams & c. in Europe; but plain water will become so hard as to require a mallet and knife to break it. Upon applying the bulb of a thermometer to one of these pieces of ice, thus frozen, the quicksilver has been known to sink two or three degrees below the freezing point: so that from an atmosphere apparently not mild enough to produce natural ice, ice shall be formed, collected, and a cold accumulated, that shall cause the quicksilver to fall even below the freezing point. The promising advantages of such a discovery could alone induce the Asiatic (whose principal study is the luxuries of life, and this may well be called such, when I have often regaled with ices when the thermometer has stood at 112°), to make an attempt of profiting by so very short a duration of cold during the nights in these months, and by a well-timed and critical contrivance of securing this momentary degree of cold, they have procured to themselves a comfortable refreshment as a recompense, to alleviate, in some degree, the intense heats of the summer season, which, in some parts of India, would be scarce supportable, but by the assistance of this and many other inventions.

XI

USES OF THE SON AND MANUFACTURING OF HINDOSTAN PAPER

(By Lt Col Ironside [published 1774].)

This useful plant,[1] I believe, is cultivated all over Hindostan. The seeds are sown in July, before the rains begin; they should be sown near to one another, to make the stem rise higher, more erect, with fewer branches, and to increase the produce. It flowers in October, and is taken up in December.

The black ladies use the seeds, reduced to powder and mixed with oil, for their hair, upon a supposition, that this composition will make their hair grow to a great length, which they are very fond of.

From the bark are made all kinds of rope, packing cloths, nets, & c. and from these, when old, most of the paper, in this country, is prepared; for these purposes, the fresh plant is steeped four days in water, afterwards dried, and treated as the cannabis for hemp, to which it is so similar when prepared, that Europeans generally suppose it to be the produce of the same plant.

As the substances, producing cloths, ropes, and paper, are few in present use, this plant may perhaps be cultivated with advantage, in some of the British West India Settlements, and in other countries destitute of hemp and flax. It is not improbable, that it may be raised in the warmer climates of Europe, as it ripens here in winter. I cannot say, what soils it may refuse; where I have seen it, in the greatest plenty and perfection, has generally been upon an earth composed of clay, calcareous grit, and sand.

There are other vegetable substances used here for the purpose of rope making; one of them is a species of the hibiscus, a description of which I propose for the subject of another paper: I can scarce doubt, but that it is only for want of experiments, we have not a greater number of vegetables rendered useful in this manner. The class *Monadelphia*, of Linnaeus, promises fair for trials of this kind.

THE HINDOSTAN METHOD OF MANUFACTURING PAPER

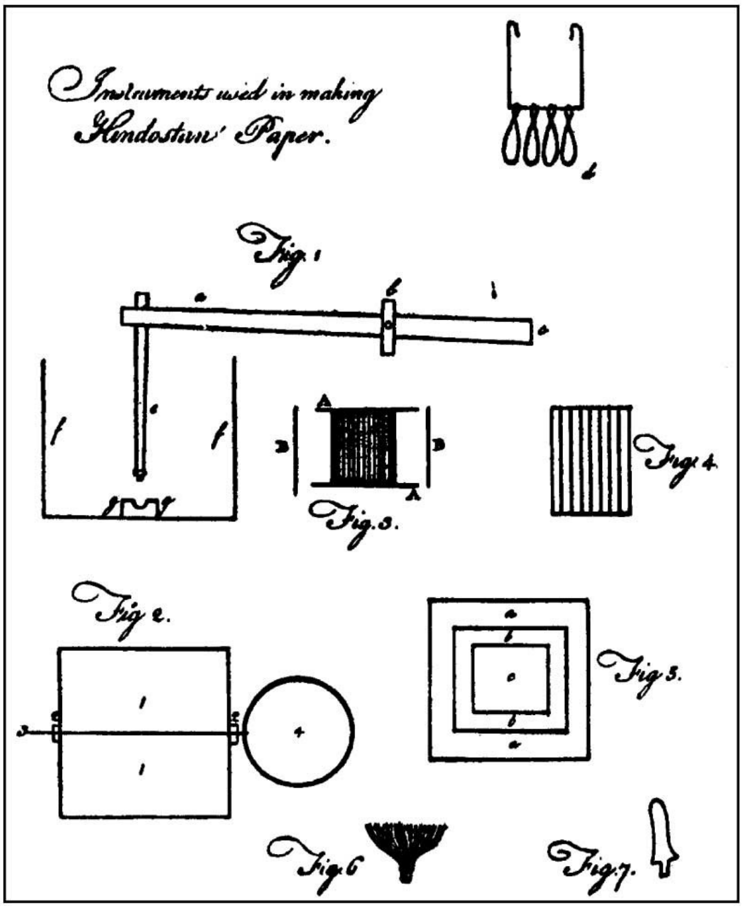

DIAGRAM I

The manufacturer purchases old ropes, cloths, and nets, made from the *son* plant, and cuts them into small pieces, macerates them in water, for a few days, generally five, washes them in the river in a basket, and throws them into a jar of water lodged in the ground; the water is strongly impregnated with a lixivium of *sedgimutti*[2] six parts and quick lime seven parts. After remaining in this state eight or ten days, they are again washed, and while wet, broken into fibres, by the stamping lever, *Fig 1.* [Diagram I], and then exposed to the sun, upon a clean terrace, built for this purpose; after which, they are again steeped, in a fresh lixivium, as before. When they have undergone three operations of this kind, they are fit for making coarse brown paper; after seven or eight operations, they are prepared for making paper, of a tolerable whiteness.

The rags, thus prepared, are mixed with water in the cistern, (*Fig.2*) at the edge of which, the operator sits, and removing the stick, he extends the screen (*Fig.3*) upon the frame (*Fig.4*) with which he agitates the water in the cistern, until it appears of a milky whiteness, by the floating particles of the rags; he then dips the frame and screen, in a perpendicular manner, and raises them gently, in a horizontal position, to the surface of the water, where he gives the frame a gentle motion, from side to side, or from end to end, to make the particles of the rags fall in an equal layer upon the screen, and then he lifts them out of the water, and rests them for the space of a minute upon the stick 3 (*Fig. 3*). After repeating the dip once more in the same manner, the new sheet of paper is formed; then, taking off the extensors, *BB*, of the screen, he rolls inwards, for about an inch, the upper part of the screen and sheet, by which means, so much of the sheet will be separated from the screen; the screen is then inverted, and the already separated end of the paper is laid upon the mat (*Fig. 5*), and the screen is gently raised from the paper. In this manner he forms sheet after sheet, until he has made 250, his day's task, laying them all upon the first sheet, in a regular manner; then he covers the whole with a coarse cloth of the *son*-plant, equal in size, with the paper; above this he lays a thick plank, somewhat larger than the paper. This by its weight presses out the water from the wet sheets; to assist which, the operator sits upon it for some time. Then the heap is set to one side until morning, when the sheets are taken up, one by one, and spread with the brush, (*Fig. 6*), upon the clean plastered walls of the house; as they dry, they readily peel off, and are spread upon a clean mat or cloth, and with a piece of blanket, dipped in thin rice paste water, rubbed all over, and immediately hung up, to dry, upon strings run across the house for this purpose. When sufficiently dried, they are cut into a quadrangular form, according to a standard sheet, which serves as a guide to the knife (*Fig. 7*). From this operation, they are carried to another person, who rubs every sheet smooth with a globular piece of moorstone granite, which he holds in both hands. Then he folds the sheets for sale. The finer paper is polished a second time. All the cuttings, and damaged sheets, are trampled to pieces in water, and renovated as above.

INSTRUMENTS USED IN MAKING THE PAPER (DIAGRAM I)

Fig. I a. A stamping lever, ten feet long, and seven inches squared timber.

b. Two pieces of wood, fixed in the floor, to support the axis of the lever.

c. This end of the lever is pressed down by the feet of two men.

d. Is a stick, suspended from the roof of the house, to which are fastened four ropes which support the arms of the workmen.

e. The head of the stamper four feet long, and four inches squared timber, bound and shod at the point with iron.

ff. A perpendicular section of a terraced cistern, dug in the ground-floor about 4 or 5 feet square.

gg. A square stone, in the bottom of the cistern, excavated in the middle, to receive the head of the stamper, by which the rags are beat to pieces. A person is stationed in the cistern, to supply the stamper with rags.

Fig. 2 1.1. A terraced cistern, dug in the floor, 4 or 5 feet square, having two little eminences.

2.2. At the edge, to support the stick.

3. Occasionally.

	4.	A jar, lodged in the floor, to hold in readiness the prepared rags.
Fig 3		Is made in the manner of the Chinese bamboo window-screens. The transverse lines are fine rush, or a grass, neatly bound with horse hairs, which makes the longitudinal lines.
	AA.	Two sticks, to which the screen is fastened, and extended by the two sticks.
	BB.	Occasionally.
Fig. 4		A form of wood, with seven bars, to support the screen (*Fig. 3)*. The bars are so fixed, as that their acute edges only touch the screen, that there may be no obstruction to the passage of water through the screen.
Fig.5	aa.	Is a terrace, 4 or 5 feet square, inclined a few inches, that water may readily run from it.
	bb.	A mat or board laid upon the terrace.
	c.	The new formed sheet of paper laid upon the mat.
Fig. 6		A flat hair brush for spreading the wet paper upon the walls of the house.
Fig. 7		The double edged knife with which the paper is cut into a proper form.

Notes

1. [The San: ºÉxÉ] This plant is described by Linnaeus, under the name of Crotalaria juncea, vid. Spec. Plant. 1004. A figure of it is given by Ehret in Trews Plant. Select.t. 47. and another in the Hort. Malab. 9.p. 47.t.26. Both these figures are good.

2. Sedgimutti is an earth, containing a large portion of fossil alkali. The *natron* (Transliterated from the original in Greek: *Editor.*) of the ancients. It is found in great plenty in this country, and universally used in washing, bleaching, soap making, and for various other purposes.

XII

INDIAN AGRICULTURE

(By Major General Sir Alexander Walker (circa 1820))

Agriculture of Malabar. Hindoo Husbandry in general—Condemned by Europeans. How far that censure is just? Their ploughs and implements of Husbandry. The principles of agriculture understood but impeded by the want of capital and impoverished condition of the people. Various opinions and statements. Tanks, Drill Ploughs: irrigation and transplanting. Opinion on the agriculture of Guzerat and Deccan. Malabar Husbandry. Rice—condition of the people different: large farms. Proprietors. Tenants. Slaves and hired Labourers. Soil.

Agriculture is the art of cultivating the ground. It is the art of raising all kinds of trees, plants, fruits and grains.[1] It is in fine the most effectual and expeditious method of procuring abundant harvests. This system cannot be perfect without the use of a considerable number of tools and instruments, and of animals subdued to labour. The system will be more or less laborious and troublesome, according to the nature of the climate and soil. These are simple and obvious propositions to which every one will give his assent. It is necessary however that they should be remembered in the course of the following remarks. The state of agriculture in Malabar will form a strong contrast, with that of the first Husbandmen, who had neither ploughs nor beasts of burden. It will also be admitted, that the art of cultivating the soil is the most important of human labours. It is the first step in the progress of civilisation: a compact and numerous population is the result of the industry and ingenuity which produces food.

It is on the power of augmenting the means of subsistence, that the increase of the people depends.

In Malabar the knowledge of husbandry seems as ancient as their History. It is the favourite employment of the inhabitants. It is endeared to them by their mode of life, and the property which they possess in the soil. It is a theme for their writers; it is a subject on which they delight to converse, and with which all ranks profess to be acquainted. They have provided a code of rules for good husbandry. A system is laid down for the proper cultivation of the soil. The rights of the proprietor and of the mere occupier of land are distinguished and explained. The Husbandman is protected. The proprietor is secured against bad management, while the cultivator or improver is encouraged. There is a curious analogy between their agricultural Code and that of the Scandinavians. The customs of both people gave a legal sanction to the privileges of the cultivator. The duties of the landlord and the tenant are defined; those of the Master and servant.[2] The Bondi and the Chirmir were the Husbandmen; they were the slaves of the soil, but yet under a legal protection. The price of labour was paid in Victual: this practice was anciently in Malabar, and is still in many instances followed. The farming leases contained arrangements for the management of the land. Another unfortunate resemblance consisted in obliging the peasants and artisans to work at low rates for Government.[3] One of the most remarkable of the rites of Hindoo worship probably owes its origin to their respect for agriculture. Their sacred Bulls, and their superstitious regard for the cow, have their foundation in the great service they rendered to husbandry. Under all these circumstances of favour and encouragement, we should expect that it would be the study of this people to improve the art of cultivating the ground, and that they would in such a length of time have discovered the most convenient and effectual instruments for the purpose. This however has been strenuously denied by those who wish to accommodate the ideas and habits of European Husbandry to that of Malabar. They reproach the Hindoos for employing rude and imperfect instruments. This censure cannot apply equally to every part of India where various instruments are in use, and of different construction. The plough is the first and most important machine in agriculture. In Guzerat it is a light and neat instrument. It has no Coulter but has a sheathing of iron: the furrows of the Husbandman are as straight as a line, and of sufficient depth to produce the most abundant crops. This is the real and only useful test of good farming.

The form of the plough in Malabar is nearly the same, but it is still lighter, and more rudely constructed. A man may carry one of them on his back. They are nevertheless convenient, accommodated to the soil and the labour. The structure of these instruments, all over India is very simple; but they answer the purpose of the Husbandman where the soil is light, unobstructed by stones, and softened with water.

In a climate where the productive powers are so great, it is only necessary to put the seed a little way into the ground. If it was buried deeper, it would rot and decay before it could germinate, or it would remain dormant in the earth. This is the case with several roots and seeds, when they are put deep in the ground and as it were interred; the process of germination ceases. It remains dormant for years, until the seed is again brought to the surface, and exposed to the vivifying rays of the sun.

It is not necessary in this mild and regular climate, to protect the seed from frost and cold. Experience is the best test of every thing. It must be a strong proof that the Indian plough is not ill adapted for its purpose, when we see arising out of the furrows it cuts, the most abundant and luxurious crops. What can be desired more than this? The labour and expense beyond this point must be superfluous. The Indian peasant is commonly well enough informed as to his interest, and he is generally intelligent and reflecting. This is the character of his class everywhere. He is attached to his own modes, because they are easy and useful; but furnish him with instruction and means, and he will adopt them, provided they be for his profit. He will not be led away by speculation and theory, which he cannot afford to follow; but he will not refuse any more economical, and less laborious mode of cultivation. He must have prejudices and ancient habits, which it would be difficult to shake; but let him clearly understand that the change would give him less trouble and better crops, and he would adopt it.

They have been always ready to receive the roots and seeds of Europe, that suited their climate, and have adopted several which they found to answer their purpose into their regular course of cultivation. All over the world men are attached to their early habits and ancient customs. The History of our own artists and manufacturers would afford many strong instances of this. Although men of superior education and intelligence, it has often been very difficult to make them alter their established methods after science and philosophy had detected their errors.

I remember that almost 40 years ago an experiment was made on Salsette by delivering to the natives English ploughs and agricultural implements. Some active and enterprising Mahrattah Husbandmen who had but few prejudices were procured: a village was built for them, they were furnished with seed and cattle. They entered on the trial of their own accord and choice. Having adopted the measure it was their interest that it should succeed, and there was no reason that I could ever discover that it failed through any negligence or misconduct of theirs. That it did fail however is certain, and as usual we imputed the failure to the prejudices, sloth, and obstinacy of the natives. I firmly believe however that they judiciously rejected the whole of the cumbrous European machinery. They objected that the plough was too heavy: that the labourer and his oxen were needlessly fatigued: that it therefore performed less work, and that this was not better done for the purpose required than the work of their own plough. It was next observed that the plough was too costly, and similar objections were made to the greatest part of the European equipment. I would not say that this experiment was decisive, or that they have nothing to learn from us, but before we charge them with ignorance and obstinacy for neglecting to adopt our recommendations, we should first be sure of two things; that the new system would give them more abundant harvests, at less expense and labour; and that we have taken all the means and care that were within our power, for their instruction in the art? It should also be well considered how far our agricultural process is suited to the cultivation of rice, the great crop of India, and of which we have no experience.

The figure and power of the instrument must be suited to the soil and climate. The American plough of Rhode Island does not weigh more perhaps than 40 lbs. It has no Coulter and a man can easily carry it in his arms; but it would be absurd to expect that this plough would answer any where but in the lightest soils.

The agricultural society which has been formed in Calcutta may diffuse knowledge and correct some errors: they contemplate the introduction of new and useful plants; the improvement of implements of husbandry and stock;[4] but the Indian Husbandman must be rendered independent and furnished with capital before he can enter into the expensive details and machinery of the English farmer. It can be of little importance to him to rear stock for the purpose of food, where it is only eaten in any quantity by a handful of Europeans. Even this encouragement has generally, if not always, been sufficient to secure at the European stations, an abundant supply of excellent and wholesome meat.

We ought also to remember that India has very little occasion for the introduction of new plants for food. There are more kinds of grain cultivated perhaps, than in any other part of the world. She has also a vast variety of nutritive roots, and as a fruit, the plantain alone supplies her with the most nourishing diet.

The potato is cultivated in many parts of India; and I have seen Bramans making their repast on it; but the yam is equally pleasant, and perhaps a more alimental food. I am at a loss to know what essential present we can make to India. She has all the grains that we have and many kinds more of her own. If we should give her some fruits and vegetables, we should first be certain that they are agreeable to her taste. Most of our fruits would be too sour, or would degenerate in the climate. The instrument of taste is likewise very various. There is a national as well as an individual relish for food. It is unnecessary to look for examples, as every man's own experience, and every nation of Europe will supply them.

Nothing should surprise us more in the present condition of the Indian cultivator than his persevering industry, and well cultivated fields.

Any other than a people of a very buoyant spirit would have sunk under these circumstances.

The Hindoos have been long in possession of one of the most beautiful and useful inventions in agriculture. This is the Drill Plough. This instrument has been in use from the remotest times in India. I never however observed it in Malabar, as it is not required in rice cultivation in which its advantages have been superseded by transplanting. The system of transplanting is only in fact another method of obtaining the same object as by Drill Husbandry. It would be but just to adduce this, as another proof of the ingenuity of this people and of their successful attention to this branch of labour. They have different kinds of ploughs, both Drill and common, adapted to different sorts of seed, and soils.

They have a variety of implements for husbandry purposes, some of which have only been introduced into England in the course of our recent improvements. They clean their fields both by hoeing and hand weeding; they have weeding ploughs, which root out and extirpate the weeds. A roller would be useless on rice grounds, which are always wet, and frequently an equal mixture of water and mud. The place of the roller is supplied by an instrument which levels or smooths the ground, without turning on an axis. They have also Mallets for breaking clods, the usual assortment of Hoes, Harrows and Rakes.[5]

It has been objected to these instruments that they are simple, clumsy and crude. This does not however make them less useful. Simplicity cannot surely be counted a fault; in some of our districts the plough is by far too complicated a machine. They are not unhandy to the people who have been in the habit of using them. They appear awkward to us because we have not been in that habit, and because the Indian Husbandman can afford to throw away nothing on ornament. The same instrument painted and smoothed by the plane would have given a very different idea of its value. The judgement of the eye decides more than we imagine. All this however depends rather upon taste and opulence, than on utility. The circumstances of an Indian Husbandman are not to be compared to those of our substantial tenants. They can study effect and appearance, which are in fact essential to their credit as good farmers. It is not however very long since we have painted and polished our ploughs. I have seen them within these few years in some parts of the country covered by the unremoved bark of the tree.

The numerous ploughings of the Hindoo Husbandman have been urged as a proof of the imperfection of his instrument; but in reality they are a proof of the perfection of his art. It is not only to extirpate weeds that the Indian Husbandman reploughs and cross-ploughs; it is also to loosen the soil, apt to become hard and dry under a tropical sun; and hence it becomes necessary to open the earth for air, dew and rain. These advantages can only be obtained by exposing a new surface from time to time to the atmosphere. In India dews fall much more copiously than they do with us, and they are powerful agents in fertilising land. Weeds also increase with a quickness, and a luxuriance, of which we can form but an imperfect idea in this country. These are sufficient causes for the frequent operation of ploughing, without the necessity of blaming either the Husbandman or his implement. The frequency of ploughing must depend every where on the nature of the soil, its situation, and the purpose for which it is intended. In some cases, our farmers in this country, plough three or four, and even as often as six times.[6]

It is the practice in many parts of India, to sow different species of seeds in the same field. This practice has been censured, but it is probably done for the same reason that our farmers sow rye grass and clover with wheat, barley; or oats; tares with rye; beans and peas; vetches and corn, etc.

It has been found by experience that these crops not only thrive in the same field; but improve each other. Rye and oats for instance, serve to support the weak creeping tares, and add besides to the bulk of the crop by growing through the interstices. Clover and rye grass are sheltered by the corn. This analogy will apply to the Husbandry of India. These similar experiments may be carried further, where the climate and soil are superior. In India different kinds of seeds when sown in the same field are kept separate by the Drill, or they are mixed together, and sown broadcast. In the last case they are commonly cut down as forage. A plant called sota gowar, is sown broadcast with sugar cane, in Guzerat. The gowar serves as a shelter to the sugar cane, from the violent heat of the sun, during the most scorching season of the year. Joar and badgery are sown together, in the same country late, not for the sake of a crop, but for straw, which is very nutritive, and very abundant. This is one of the instances in which the natives provide a green crop for their cattle. Other grains are sown both together and separately, merely for their straw. Soondea, darrya joar, rateeja and goograjoar are sown together: but with the exception, of goograjoar which is allowed to ripen, the rest are reaped while they are green.[7]

It is evident that these examples are not founded on bad principles, and that they are in conformity with the best practice of farming. They evince the care of the Hindoo Husbandman to provide food for his labouring cattle. This is an object to which I have generally seen him attentive; but in many parts of India during the dry season it is extremely difficult, and often exceeds the impoverished means of the cultivator, to lay in a sufficient supply. He is sensible enough of the want, and does his utmost to scrape together, all the heterogeneous substances that are within his reach. In some parts of India, hay is not made, in other parts it is a regular crop, stacked and preserved. This is the case in Guzerat, and some other pergunnahs. The hay is cut down not by the scythe but by the reapers hook: It is dried and brought home in carts. The stacks are generally of an oblong shape something like our own, but often of much larger dimensions than any that I have seen in England. The stack is not thatched merely, but covered and protected, by a moveable roof. In those parts of India where hay is not made and which are I believe unfavourable to this kind of crop, the cattle are fed with the roots of grass, very like our fiorin, with straw, and especially with the straw of joaree, all of which are considered to be very nourishing food. The roots of this grass are preferred by our own people in the Carnatic to hay. Besides the Hindoo in many parts of India, prepares various crops of pulse, solely for the use of his domestic animals. In some places he feeds them with carrots. Lately, an ingenious gentleman has sown with great success, near Kaira in Guzerat, clover.[8] The seed was obtained from Bussara and produced a most abundant crop. It fed a cavalry regiment, and kept it in excellent order.[9]

It would require a volume to pursue all the details of Hindoo Husbandry. I shall however mention some other principal features. In many parts of India the fields are fenced and enclosed. This is the case wherever the people live in quiet and security. It is sufficient to show what was the ancient practice, when the Government was good and the country not exposed to the ravages of war. In Guzerat this attention to the security of property was seldom neglected. Even during the native Government, the Ryot was protected in his revenue engagements; in case he might not be able to fulfil them, either from war or adverse seasons. This was effected, by exempting him in his lease, on the event of any of these circumstances occurring, by the phrase 'Asmani Sultanee'. The enclosures are generally of a square form. The divisions are seldom very large, and are of unequal sizes according to the judgment, interest, or taste of the proprietor. They are remarkably neat, kept clean, and well dressed. These fields have frequently broad grassy margins which are left for pasture, such as are seen in some parts of Yorkshire. The whole world does not produce finer and more beautifully cultivated fields than those in Guzerat. In the neighbourhood of towns, they are commonly planted at the edge, with fruit, and other trees. This gives them the appearance of our Hedge-rows, and they may be compared to the finest parts of England.

This appearance is not peculiar to Guzerat: It may be found in many other countries of India. I am desirous that these remarks should not be considered as extending to Bengal, of which I have had no personal observation. The gentlemen who have resided in that province seem to agree in giving an unfavourable account of its agriculture, and of its people. They describe the natives as characterised by the lowest and most disgusting vices. If this be so, they should not be considered as affording a just notion of the rest of India. It has however actually been by this mark that the public judgment has been in a great degree formed of the qualities of perhaps 200 millions of human beings, spread over a vast country, and divided into many nations, some of whom are totally unknown in Bengal. This species of amalgamation has happened from the superior wealth and political importance of Bengal, from our connection with it, and from the fallacious practice of drawing a universal conclusion from a particular fact.[10]

My own experience agrees entirely with the neat, accurate and comprehensive view that Colonel Wilks has given of the Husbandry of Mysoor.[11] I have seen from Cape Comorin to the Gulf of Kutch details of the most laborious cultivation, of the collection of manure, of grains sown for fodder, of grain sown promiscuously for the same purpose; of an attention to the change of seed, of fallows, and rotation of crops. The rotation may sometimes be imperfectly followed; but it is a system understood and acted upon throughout India, with more or less skill and intelligence. All the changes however which are necessary for preserving the fertility of land in Europe, may not be equally essential to the fecundity of soil, under a climate like that of India. In America, virgin or new land continues for many years to produce crop after crop, without the assistance of manure. In Lithuania there is a regular succession of the same crops: even in Britain in the neighbourhood of towns, where there is a perpetual command of manure, the regular rotation is frequently neglected without impoverishing the land. In the West Indies, where there is no cultivation but the sugar cane, the same crop is constantly produced.

We may see from all these instances, that though it is a rule of good husbandry to avoid a frequent repetition of the same species; yet it may under particular circumstances be entirely disregarded without any bad consequences. Some places are more indebted for good crops to the natural fertility of their soil than to artificial labour and skill.

Rice is supposed to be the least exhausting of any crop. It occupies the ground but a short time and binds it less than any other culmiferous plant.[12] The water and moisture by which it is continually surrounded, keeps the soil soft, divided, and pulverised. It is by some causes like these, that the Indian farmer is enabled to repeat the same crop for many years in the same field with this species of grain. We must allow something also to the extraordinary fruitfulness of the soil, and the regularity of the climate.[13]

In every part however that I have visited the application of manure for recruiting and restoring land is well understood. The people seem to have all the resources that we have in this respect. By littering their cattle with straw, they increase the quantity of manure. They collect leaves, and putrescent substances. When they have no means of rotting the straw, they mix it with dry dung, old grass and even branches of trees, which they place in a heap and set fire to it. The ashes are then spread on the ground. The slime and bottoms of tanks are dug up, and considered to be a valuable manure.

It may be considered as a part of Indian Husbandry, though by no means a universal custom, as it is only in particular situations practicable, to set fire to the long and luxuriant grasses which the cattle have not consumed. This is not practised in arable husbandry where it is unnecessary. The stubble of a rice field is ploughed into the ground in the same way as with us; but it is resorted to for reducing the natural pastures of the hills, which are beyond the reach of the plough. These luxuriant grasses are burnt and decomposed in order to nourish a new growth. It is the same operation, and for the same purpose, as that of burning heather for improving sheep pasture. This is usual practice in the Concan and Deccan; but it is not so generally resorted to in Guzerat, or in Malabar, as it is not so well suited to the circumstances of those countries. The practice of burning grass is only followed on bare and naked mountains. In those that are covered with trees, such as the Ghats in Malabar, it would be destructive, and is not therefore had recourse to. In the Concan, and where the high lands are generally without wood, and where the grass grows to the luxuriance almost of reeds, the burning system is pursued. Wherever it is practised, the natives consider it as a proof of barrenness, and caused by a curse of one of their gods. The heat of the sun, natural and artificial moisture, and the inundations of rivers, keeps the soil in India in a state of perpetual fecundity and renders it fruitful year after year, as was the case under the same circumstances in Egypt.

The Indian farmer is again reproached for using his dung for fuel; but an explanation of the fact will in some measure vindicate him from this censure. The dung which is employed in this way (a small quantity after all) is obtained principally from what the animal lets fall on the high road, and which would otherwise be lost. Boys and girls are employed with baskets to gather it up from the roads and streets as in our own country. These children are seldom those of the cultivators, but of any of the inhabitants, most commonly of very poor people, who mix the fresh dung with charcoal or straw, make it into cakes, and dry them in the sun.[14] The boys and girls may be seen in many parts of the North of England employed in the same way; and I have been told that in no very remote time a similar manufactory was carried on all over this country.

I have already mentioned the Drill Husbandry, as an invention of the Hindoos; that of transplanting which has the same object in view, is equally useful and beautiful. It gives the field the regularity of a garden, and every vacant space is filled up. The operation of transplanting is calculated to afford one fourth more of produce than the broadcast method of cultivation. Many of the details of Hindoo Husbandry are curious and original.

The practice of watering and irrigation is not peculiar to the husbandry of India, but it has probably been carried there to a greater extent, and more laborious ingenuity displayed in it than in any other country. The vast and numerous tanks, reservoirs, and artificial lakes as well as dams of solid masonry in rivers which they constructed for the purpose of fertilising their fields, show the extreme solicitude which they had to secure this object.[15]

These works were not always executed at the expense of Government; they were often defrayed by the zeal of wealthy individuals, and sometimes by women. The names of these benefactors are still preserved; but they frequently serve only to commemorate a dry spot, and to point out where a tank had been. Perhaps no circumstance can more strongly show the decline of India than the decay of those works, which were at one time necessary to supply with food an abundant population. The bottoms of many of the tanks are now converted into rice fields, and the waters of others run waste. The dry bottoms still retain moisture, and as they are enriched with the alluvial deposits of a former age, they are eagerly seized by the Husbandman, who is sure to be rewarded by an abundant crop. The ruin of these beneficent labours cannot but give to the traveller in passing, melancholy and unpleasant reflections.

The Mohammedans were probably excited by the example[16] and intercourse of the Hindoos to cultivate the arts of peace, and they also employed themselves in constructing many magnificent reservoirs for water. There was a great distinction however in general between the works of the two people.

For the most part the tanks of the Musselmans were built for luxury, ostentation and ornament. Many very expensive ones were unfit for irrigation. Ali Merduns canal however, a noble and useful work, was an exception to this remark.

Besides the great reservoirs for water, the country is covered with numerous wells which are employed for watering the fields. The water is raised by a wheel either by men or by bullocks, and it is afterwards conveyed by little canals which diverged on all sides, so as to convey a sufficient quantity of moisture to the roots of the most distant plants.[17] When these are seen in operation it gives the most cheerful picture of quiet and useful industry, that can occur even to the imagination. The very sight of it conveys to the mind peace and tranquillity.

I must repeat that I have seen in India the most abundant crops 'the corn standing as thick on the ground as the land could well bear it'; fields neat, clean and generally without a weed. Infinite pains are taken to extirpate these, and several ingenious instruments have been contrived for the purpose.

It is hardly possible that a weed can be found in a transplanted field, where every stalk is put in by the hand, and carefully planted.

The Husbandman in fine labours incessantly to increase his produce, varying his operations according to circumstances, and acting always when he can, on fixed principles. A system of rotation is attended to, but the alluvial deposits make it in many places unnecessary, and local peculiarities, local oppressions, and the want of resources compels the cultivator to forego many advantages: he is obliged no doubt by so many pressing necessities too often to deviate from the best plan; to submit to such shifts and expedients as are within his power. Some allowance should be made for the circumstances of the people, general as well as particular. Some compassion should be felt for their situation, and when we see one district highly cultivated, another in poverty, and the wrecks everywhere of a greater agricultural prosperity in former times, would it not be equitable and just to conclude that ignorance and stupidity were not the sole causes of these anomalous appearances? The flying surveys, partial, and hasty reports that have as yet only been made of their agriculture, are not to be depended upon. It would require the leisure and application of years, much patience and knowledge of the subject, and a judicious allowance for the peculiarities of the climate, to appreciate either the merits or defects of Hindoo Husbandry. In the present political state of India; the connection and dependence of the greatest part of that fine country on the British Government, renders it an imperious duty for us to use every prudent and proper means for the improvement of its condition; but we should be careful in these attempts at amelioration not to throw it back, and to obstruct its progress, by too hastily condemning the practices of the country, which have been sanctioned by experience, and have their utility in local circumstances. The minds and inclination of the people should be consulted wherever their own interests are concerned. In general their experience is the best guide. It is in vain to suggest expensive improvements where there is no capital, where the rent is taken as a tax by Government, and where the proprietory right of the soil is disputed. The cultivation of grain in some places yields no profit to the Husbandman, beyond his mere subsistence.[18] In this case there is neither means, nor stimulus for improvement. Notwithstanding all these disadvantages, the state of agriculture among the Hindoos is respectable: I may say wonderful. Some of the details of their management would furnish information to the European farmer; when they follow a bad system, it is not from ignorance of the true principles of the art, but from poverty and oppression; remove these and improvement would follow. The Hindoos, whatever may be their moral qualities, are a temperate and an industrious people, knowing, and well acquainted with their own interests. In the course of our intercourse with them they have adopted many things from Europe, and they are continually adding when it suits their taste and convenience. If their system of agriculture is bad, they will alter it as soon as we can show them a cheaper and an easier way of procuring more abundant harvests; but this will not be produced by mere theoretical recommendations. We should succeed in altering many of the habits and practices of India, provided it were possible to compel our own habits to mix with the labours of the people. It is more than probable that any great change depending on the introduction of European arts and manners will be introduced by the Half-castes (i.e., those of mixed Indo-European parentage.—*Editor.*) who are now spreading and multiplying in the usual increasing ratio of population. I shall conclude these general remarks by an extract from a letter of a valuable friend whose intelligence and opportunities of observing the practice of Indian Husbandry, are not I believe exceeded by any man in that country.

'In Guzerat, and indeed in the Deccan, but especially in Guzerat, careful and skilful agriculture, is probably, as much studied as in England. In many points an English farmer might condemn the practice at first sight; but in time he would learn, that much of what he did not approve, under an idea that the same system in all respects that succeeds in England ought to be followed here, was of the first importance; was in fact what constituted the great means of success in this climate and that to depart from the existing practice would be folly. For instance as to ploughing in this country, it is condemned as not being deep enough. The native however knows from experience that the soil at the surface, and which has been well heated by exposure to the sun, is that which yields the best return. It is not uncommon to see them before the hot season plough their more valuable lands roughly, so as to expose as much as possible of the soil to the revivifying influence of the sun. It is a fact too, that in most soils in Northern Guzerat, the lands are more productive, when kept continually from year to year under cultivation, than when allowed to lie fallow: such soils however as improve by a year or two's respite, always receive it. This is not uncommon in the Surat, and even in the Broach district, and in some parts of the Deccan. One of many proofs that were requisite, the system of the natives, is too well founded on experience to reject it.'[19]

It is now time to return to the more immediate subject of this article, the husbandry of Malabar. The practice varies in many respects from the Northern parts of India, or where they grow wheat, and other grains which are not cultivated in Malabar. The practice is regulated by the soil, the surface and the crops. In each region of India there is some peculiarity in the mode and articles of cultivation, which must be adapted to the climate, the difference of seasons, and the nature of the ground.

In Malabar; agriculture, is an important, and an honorable occupation. This is the consequence of this species of property being well established, and an interest created which requires, that every proprietor should understand something of an art on which not only his comfort, but his support must depend. Most of these men therefore are qualified to direct the labours of their cultivators, and many of the Nayrs hold the plough themselves. Some of the proprietors farm their estates to tenants, and live on the rent; but most of them reserve some land in their own hands, and others have larger farms. The order and arrangement are not different from what we find in Europe. The size of the farms vary from one plough to 20. The Chirmirs perform a great part of the labour, but not the whole. Every estate has some Chirmirs attached to it. Some of the largest farms have from 50 to 100 Chirmirs, men, women and children. The oxen and cows are each about the same number as the slaves. Such farmers have also a number of hired servants, and very often a Karrigar or superintendent, who directs the labour of the rest, but does not work himself. The duty and character of this person resembles that of our Bailiff or Overseer.

These establishments are respectable, they convey an air of wealth and comfort, seldom seen among the peasantry in other parts of India. They recall to mind the proprietors and farmers of our own country.[20]

I do not mean to enter into all the details of Malabar Husbandry which will be best explained by the annexed table. (Omitted here.—*Editor*) A general description however is necessary. The land is generally well fenced and subdivided. The long, narrow and beautiful vallies form indeed natural divisions. The artificial divisions are commonly small, for the convenience of irrigation, and to mark the shares of individuals. The fields, or divisions, are formed into neat and oblong squares. In preparing the ground for rice, they plough twice, and even thrice according to circumstances, before they sow. The first operation is to surround the field with banks, and then to overflow it. The banks are about two feet broad, and raised rather more perhaps above the level of the ground. They serve as well as to keep in the water, as footpaths. Without them the people would be obliged to wade through mud and water, either when they wanted to inspect their fields, or in prosecution of many of their necessary labours. The depth of water in a rice field depends on the particular situation; it varies from six inches to a foot, and even a foot and a half.

In some cases a rice field is kept under water until the second ploughing. It is then almost an equal mixture of mud and water. The cattle in this state are of as much use as the plough. The water first rots the weeds and grass, and afterwards nourishes the plant. Water is the most necessary agent of vegetation. The seed corn is sometimes, but not always, soaked for 20 or 30 hours in water. It is then laid in a heap for several days; in this state it shoots and grows. The ground is finally prepared, either for sowing or planting, by dragging a plank over its surface by cattle. This levels and smooths the ground; and mingles every thing together. The water is allowed to run out before the seed is sown. It is then sown broadcast, or planted.

The planting or transplanting is performed in this manner. When the rice plants appear a few inches above the ground, they are taken up, tied in little bundles, and again put into the same ground, or removed to another field as may be necessary or convenient. This work is performed by the hand, and very commonly by women. The field is again overflowed and kept so until the grain is nearly ripe. The banks are then finally cut and the water escapes.

Generally speaking about three parts of the stalk of the plant remains above the water. The process in Bengal is very different from this.

There is cultivated in Malabar upwards of fifty kinds of rice. They are each distinguished by a separate name, by some peculiar quality, and different modes of cultivation are of course pursued. Some kinds grow on the hills and do not require irrigation. These are called Poonum and Modun. They are much longer in ripening than the usual cultivation. There is one species which is propagated by cuttings, a mode which I never heard of except in Malabar. An account of all the different kinds of rice cultivated in this province, will be found in the tables, at the end of this article.(Omitted here.—*Editor*)

The southern parts of Malabar are more fertile than the northern parts. The former in many situations is capable of producing three crops a year, or rather in 14 months, while very few places in the latter produce two, and in the Wynaad above the Ghats only one crop is procured.[21]

Some kinds of rice are found to ripen earlier than others, and to thrive in different degrees of moisture: they have hence not all the same seasons of reaping and sowing. They have their particular situations and soil. In the husbandry of Malabar the skill of the Kudian or cultivator, is therefore exerted, to discover the grounds best adapted to each. He has discovered that it is useful to change his seed: but one crop of rice follows another in eternal succession. The hill rice requires 8 or 9 months to ripen, and that on the inundated fields but three. The hill crop is more precarious, as it depends entirely on a favourable season of rain. In the upper lands they observe a regular rotation. It is in these situations where they grow their green crops: these are confined to a few kinds of pulse, and gingelly or ellu. In these hills they plough for some kinds of culture as often as seven times. But rice is the great article of cultivation in Malabar: they also cultivate, the sugar cane and dholl; and the climate would probably answer for all the tropical plants.

The superiority of production is vastly of warm climates. The whole year is fertile. The great drawback is the want of moisture and rain. When the regular supply of water fails, nothing can prevent a sterile harvest. Malabar is however rarely, if ever, exposed to this calamity. In this respect it has the advantage of almost every other part of India. In Malabar the cultivation of rice may be seen at all seasons of the year, and at the same time in every stage of its progress. Nothing can be more rich and interesting than this picture. The appearance of the country is beautiful and various. At one view may be seen the operation of sowing or transplanting in one field: in another the plant shooting above the water, and elsewhere it is quite ripe.

The people of Malabar have two sorts of ploughs; one is heavier than the other, but they have both the same simple construction. The Malabar ploughs have only one handle. It is curious that this is the case also with the plough of the south of France, that of Suffolk, and the Shetland Islands. This is one of those resemblances which belongs to taste and fancy, rather than to imitation. We may be surprised that people who live so remote from each other, and under such different circumstances, should have come to adopt the same apparently feeble and inconvenient structure of this indispensable instrument. We can only answer, that they must have been led to it by some practical or imaginary advantage, and that habit has made it convenient.

The obstacles to cultivation here are few. A farmer in Europe would follow the same principle. His ploughs are constructed to suit the nature of the soil, and the work they have to perform. The same sort of ploughing that is necessary for a wheat crop, would not be proper in the cultivation of rice. Husbandry is never disgraced in Malabar by yoking together animals of a different species. Moses forbids the Israelites to plough with an ox and an ass together as a lesson of moral instruction: ‘Be not unequally yoked, etc.’

The Malabar plough is dragged by a pair of oxen, and driven by one man. The Husbandman repairs to the field before the dawn of day and leaves it at sunset. He takes his repast, and rest under the shade of a tree. His wife and children accompany him.

Like the Hindoos, the Greeks and the Egyptians had no Coulter to their plough. Such also are those used in the south of France, and in general in all hot countries.[22] It has been from this conjecture that tillage was invented by those nations which inhabited a light and loose soil.[23]

The ancients, also like the people of Asia, made use only of oxen in tillage. The Greeks who speak of Bacchus as the inventor of agriculture, say he was the first that brought oxen out of India into Europe.[24] We may infer from this that they considered the art of cultivating the ground, to have come from India.

The corn is reaped by the sickle, men and women engaging in this labour. It is not allowed to remain long in the straw, and is separated in the field by the ancient, and simple method of treading it out by oxen. It is evident that this method could only answer in a country, where the climate was regular, and the sun powerful. The process of thrashing, drying and winnowing, are all finished together. The grain is carried home in baskets, or in bags, which is performed by men and bullocks. It is then put into larger baskets, plastered in the inside with cow-dung, to exclude the air, and to protect the corn from vermin. It is lastly deposited in a granary. In some other parts of India the baskets are buried in the earth, but this can only take place in a dry soil and one which does not abound in springs, which is not the case in Malabar.

In Malabar the natives make use of no wheel carriages. All the labour of conveyance is performed by bullocks and men. This is the case also in Persia and among the Afghans.[25] What causes could have prevented these nations from adopting one of the most useful arts? They must have been acquainted with its advantages by their neighhours, who carry on their inland commerce on carts; and chariots seem to have been part of the warlike machinery of rude people. The nature of the country, and the rice cultivation of Malabar, are unfavourable to carriages; but these obstacles could not operate in every situation, and could not be very difficult to overcome.

It is evident that the nature of the soil, must have great influence in determining the operations of the Husbandman. The fertility of land in India, depends on the access to water, and the regularity of the periodical rains, as much as on the fruitfulness of the soil. These supplies are particularly requisite in a country where the soil is hard and cohesive during the half of the year, except on the sea-shore where it is sandy.

In Malabar the soil is classed in point of productiveness under three sorts. They form their judgment of its quality by the following experiments and process.

The first sort is called Pasheemah Koor. This is the highest quality of soil, and consists of rich clay. In order to discover its relative properties, they dig a pit about a yard deep, and as much wide. If the soil is of the kind in question, the hole will not receive, the earth that was dug out of it, when returned back, by a considerable quantity. The natives assure us that the hole cannot be made to contain the whole of the earth even by pressure, as by stamping with the foot, and beating it down with a spade, or a piece of wood. This earth is very adhesive and unctuous. It sticks when handled to the fingers like grease; hence, its name, Pashee signifies paste or grease, and Koor, kind relatively considered.

The second is called Rashee Pasheemah Koor; ground of an equal or middling sort. To determine its quality, they dig a hole as before; but on returning the earth into the hole it will be exactly filled, and appear level with the rest of the field. This earth will also stick to the fingers, but not so adhesively as the first. It has therefore the epithet Rashee, which implies a mixture of earth and sand, which are united with the rich clay of the former soil.

The third kind of soil is simply called Rashee Koor, a term descriptive of its poverty. This is very poor light land. The earth in this experiment, when returned into the hole, will not fill the pit. This soil consists merely of loose sand.

It is curious and not a little interesting that these experiments correspond exactly with those of Lord Kairns in his theory of fertilising soils. He says: 'Some earths fill not the hole out of which they were dug: some do more than fill it. Poverty occasions the former; the pores are diminished by handling which makes it more compact. Solidity occasions the latter; clay swells by stirring and continues so, till its former solidity be restored by the power of gravity.'[26] It is equally remarkable that these experiments of the Malabar farmer, should correspond with Sir H. Davy's philosophical observation; 'that the fertility of soils is in proportion to their power of absorbing moisture'. 'Alumina, or pure clay,' he says, 'is the earth to which soils owe their fertility.' He adds: 'Soil with too great a proportion of sand is absolutely sterile.'[27]

It is certainly a singular circumstance, that this theory, the discovery of science, should be understood and acted upon by the Hindoo peasants.

It has been observed that although the Hindoos live chiefly on vegetable diet, they cultivate few horticultural plants, and pay little attention to gardening. In this climate the whole country may be called a garden, and nature furnishes many things spontaneously which elsewhere can only be obtained by the most laborious exertions. Their abstemious habits are easily satisfied, and a small spot is sufficient to raise all the plants which they require: These are confined to spinnage and some of the Brassica tribe. The chilly or red pepper, some badjee or spinnage, some cucumbers and pumpkins, and a few flowers, compose the principal articles in their little gardens. This is merely because these articles are daily and hourly wanted for their culinary purpose, and to save the trouble of going into the fields for them. Cucumbers, melons, pumpkins, the brinjal, bendy, a variety of beans, or pulse, and yam, are cultivated on a more extensive scale. These are reared in the common fields, and as a regular crop, particularly the yam, which attains great perfection in Malabar. But corn and fruit trees are the great objects of attention. The soil of the Malabar vallies is alluvial earth.

They study with particular care the changes of weather and the seasons. At the full and new moon, rain and dew fall more copiously and the Husbandman regulates many of his operations by the phases of this planet.

The stars are consulted and the astrologer opens his books. But it is not altogether an idle superstition, that plants ripen and grow faster under some of these changes. It was probably with more reason, than we are aware of, that the stars were formerly consulted even in Europe, before the farmer committed his seed to the ground. It was strictly recommended that they should not begin to sow before the setting of the stars.[28] They had in Europe, as well as in India, astrologers, to foretell the seasons, and to write horoscopes.

Bacon says in his Natural History, that seeds, hair, nails, hedges, and herbs, will grow soonest, if set or cut in the increase of the moon.

The Malabars are attached, as we have seen, to a country life. The Nayrs and Namboories live in houses, at a distance from each other. Segregation is the consequence of a rural society. This is the only way in which groves can be enjoyed, and labour carried on. 'When there was not room enough for their herds to feed, they by consent separated and enlarged their pasture.'[29] It is to this mode of life, and the easy circumstances, that usually attend it, that we are to ascribe the neatness and cleanness of the houses and villages of Malabar. The same circumstances, produce the same effect on their persons. It is not a mere freedom from dirt or filth, but a neatness of dress, and a cleanliness of person from head to heel. The same neatness may be seen through every part of the country. It is displayed in their agriculture. It is not fine houses, but nature and the broad Canopy of Heaven, that they contemplate with delight. They have everywhere under their eye, magnificent and fertile landscapes. These they improve and ornament by planting fruit or umbrageous trees, which refresh the traveller.

Note

1. Goguet vol.I p.85.

2. *Edinburgh Review* No. 67, p. 201.

3. This species of forced service prevails in all despotic Governments. Service against the will was known even in ancient Greece. It was called forced service.

4. See a Journal for 1820, 387

5. See Figures of the Plough and of all these instruments from 55 to 64. [Not included in original.—*Editor*]

6. 'When I spoke of three ploughings for sheni (sic) I scarcely allowed enough: they ought to have four or even five, especially if the land be at all heavy.' Burke's letters.

7. See a very intelligent agricultural memorandum from Captain A. Robertson.

8. Lucerne, I believe.

9. The history of this experiment must be found in some of the recent dispatches from Bombay. Has it been kept up, or is it discontinued?

In a season of great scarcity, Dr. Gilder cultivated Lucerne to a considerable extent, so much so as to warrant his considering that he could grow a sufficient quantity of it for the use of a Dragoon Regiment and he offered to engage to do so, but the offer was not accepted. I believe the constant use of green forage in quarters was considered objectionable. During the same season, he found carrots useful as a food for horses, and he supplied a considerable quantity of these and of his

Lucerne to the Cavalry; but on the return of a favourable hay-harvest both were discontinued. At present many gentlemen cultivate Lucerne for their private sheds. If regularly watered and occasionally weeded, it bears cutting all the year through, once every 20 or 25 days, yielding a heavy crop. It will thus produce for several years. The natives of India have a grass of a very nutritious quality which is grown in the same way, and which may be cut every month. It was during the famine adverted to that it was brought to my notice by Bappoo Mheta, who got some of the seed from Ahmedabad. It succeeded very well, but I did not continue to grow it after hay became abundant. Lately in Khandeish during scarcity I sent to Guzerat for a quantity of the seed, but what was sent did not come. I cannot at present recollect the name of this grass, but it is well known in Guzerat.

10. In the Deccan the cultivation is as good as that in Guzerat, and the people are in every respect as active and as intelligent as well as moral and independent as those of that country. I doubt whether the Bengallers are really as depraved as they are said to be.

11. Col. Wilk's History vol.1. p.209. The whole of the note is instructive. It is the result of observation and study on the spot. It shows that the practice of the Indian farmer is founded on the most enlightened principle of modern farming.

12. Lord Kairns.

13. Rice lands are always manured to the utmost of the zamers(sic) abilities. They spare no expense in this. In the Concan they cover the fields with a thick layer of leaves, brush wood and even hay and set fire to it. Even in Bombay rice fields are manured by using hay for this purpose. This manure is not got without considerable trouble and expense, and more than this, nothing shows more the care and skill of the cultivator.

14. Which is done for fuel.

15. Khandiesh abounds with these and many of them cost vast sums of money. In the late disturbed state of that province for many years, many of them have gone to ruin, but the Government of Bombay is repairing them at a great expense.

16. We may suppose that this example produced this effect, as the character of the Mohammedans was more mild and tolerating in India and their conduct more directed to improvement and civilisation than in any other country where they have established themselves.

17. This still is the case in many parts of India as it is in Egypt. See Brace's Travels and those of Dr Slater.

18. Mr. Colebrooke's Statement of Bengal Husbandry. The extraordinary fertility of the soil in Bengal is probably unfavourable to the Hindoo Husbandman. He has always almost a super abundance. In some parts of Poland the natural fecundity of the land produces spontaneous crops of wheat. The consequence is, a most ignorant and unskillful system of husbandry. In Scotland again which owes little to nature, and where nothing is obtained without excessive labour, agriculture is indebted for some of the finest improvements.

19. Extract of a letter dated 9th April 1820. This process in fact is a species of fallow.

20. For an account of Malabar farms see Dr Buchanan for some curious and interesting circumstances. A judicious and short extract might be made. Even the Dr Buchanan speaks favourably of Malabar agriculture: this country was not in a state of oppression: here the Government did not require all the rent.

21. The contrast between the fertility of Malabar and the most fertile part of India was once strongly brought to my attention in a conversation with a native officer who was on detachment with me in the interior of southern Malabar, and who had come from the upper provinces of Bengal. His name was Baulday Sing, a name which I still have a pleasure in remembering. He was a very handsome man upwards of six feet high, and a brave soldier. Baulday Sing according to the character of his countrymen was describing in rather glowing colours the natural fertility of his native country, its beauty and all the happiness he enjoyed there. 'Then Baulday, what motive induced you to leave that fine country and to relinquish all these pleasures?' The suddenness of the question perhaps at first surprised him, but after a moment's pause he replied, 'I left my country to see strange and wonderful things, and that I might have the pleasure of relating them on my return.' 'What can you have to tell from Malabar?' 'I shall be able to tell,' said Baulday with an emphasis which showed the strength of the impression on his mind, 'that I have been in a country which yields three crops of rice in a year!' But Baulday never returned to his country.

22. Goguet vol.1, p.91.

23. Ibid.

24. Ibid.

25. Mr. Elphinstone in his account of Cabool, I think, states this fact; but it should be examined which I have not at present an opportunity of doing by referring to his interesting work.

26. Gentleman Farmer, p.367.

27. Sir Humphrey Davy's Chemistry.

28. Brown's Vulgar Errors—Columella.

29. Lock.

XIII

ON THE DRILL HUSBANDRY OF SOUTHERN INDIA

(By Captain Thos Halcott (dated 31st December, 1795 and 10th January, 1796).)

Until lately I imagined the Drill plough to be a modern European invention; but a short time ago, riding over a field, I observed a Drill plough at work, very simple in its construction, which upon inquiry I find is in general use here, and has been so from time immemorial. This led me to make some further inquiries into their mode of Husbandry here, and I find the Drill Husbandry is universally practised in the Innacondah district, in the culture of all grains, except horse-grain, and is also used in the culture of tobacco, cotton, and the castor-oil plant. In the practice of this Husbandry they have two other ploughs in use here, exclusive of the Drill plough, and the common plough: one of these has a horizontal share, and immediately follows the Drill plough at work. It is set into the earth about the depth of seven or eight inches, and passes under three drills at once. It operates by agitating the earth so as to make the sides of the drills fall in, and cover the seed-grain, which it does so effectually as scarcely to leave any traces of a drill. The other plough alluded to, is used after the corn is about eight or ten inches high. It cuts up the weeds between three drills at once, and earths-up the roots of the corn at the same time. I cannot, by writing, give you an adequate description of the three ploughs, but will send you a set of them, if you wish it, accompanied by a man who has been in the practice of working them.

I have some reason to think this Drill plough, simple as it is, possesses an advantage that the patent Drill plough does not; for I remember reading in some publication, that the patent Drill plough was defective in not dropping the grain equally; this plough has no defect of that kind. It has three teeth about eighteen inches long, and ten inches asunder; through the upper end of each tooth, near the back, is inserted a hollow bamboo of an inch in diameter, and about three feet in length, these three bamboos are set upright, and their upper ends are brought nearly together, in the form of a triangle, and inserted through the bottom of a wooden cup. This apparatus is supported and made steady by cords, in the way of shrouds, which lead to different parts of the plough.

In working the plough, the cup is not filled with grain, but is fed by hand; this labour is performed by a woman, who walks on the left side of the plough with a bag or large pocket of grain before her, her right arm stretched out, and her wrist resting on the edge of the cup; her hand is filled with grain, and by moving her fingers she lets drop into the cup as much grain as supplies the three drills in due proportion. When the grain in her right hand is nearly expended, she fills it again from her left hand, observing never to take her right hand from the cup, while the plough is in motion, as that would leave a vacant space in the field. The Drill plough, which drops the grain by some piece of mechanism, will probably never sow a field so equally as is done in this way; and here is a remedy for the defect complained of in the English Drill plough. Whether the expense of two persons to work this plough, may or may not make against its being introduced into England, in preference to that now in use, I shall leave to be determined by those who are better acquainted with the subject; yet when it is considered, that supplying the cup is a labour performed by women, and how soon an acre is sown in this way, perhaps it might not be rejected on account of the additional expense, which would be but trifling. The first cost of a plough of this kind would be but a few shillings, whereas the patent Drill plough is an expensive machine.

A gentleman who is now here on a visit, informs me that his grandfather, who farms part of his own estate, practices the Drill Husbandry, but found the Drill plough dropped the grain so unequally, that he laid it aside; and now, from a conviction of the superiority of the Drill Husbandry, uses a drill roll, which has a number of pegs upon it, and makes holes in straight lines, into which the seed-grain is dropped by hand. This is a tedious way, and he informs me has also its defects, as it is done by children whose hands, in the cold season when wheat is sown, are apt to get numb, and they often drop too many grains into each hole. However, many prefer this method to the Drill plough at present in use. Whether the plough with a horizontal share for covering in the drills is in use in England, I know not; if not, it will be an acquisition to those who practice the Drill Husbandry. I am also equally uninformed, whether the instrument used here for cutting up the weeds between the drills is known in England. It is simply three small mamoties set upon three teeth, placed at the same distance from each other as the teeth of the Drill plough.

By my sending you these instruments, you will have a better idea of them than I can convey in writing; but as I am informed by a man from the Carnatic, that the Drill Husbandry is used in some parts of it to the westward, you may possibly have seen these ploughs, and in that case it will be unnecessary.

You correspond occasionally with the Board of Agriculture; should you think these instruments would be useful in the Drill Husbandry at home, I will thank you to forward the set (The set of three ploughs was duly received by the Board of Agriculture in London and sketches of them were included (along with the above narrative) in the first volume of 'Communications to the Board of Agriculture' (1797). These sketches are reproduced here as Figures I and II. —*Editor.*) I shall send you, to them. If, however, you should find that these instruments have been already described in any publication, and that it is a matter known among Europeans, that the Drill Husbandry has long been practiced in this country, it will of course be worth no farther attention. But so far as I know at present, I am the first European that ever noticed it, for although it has been practiced under the eyes of every body in the Guntoor Circar, no one that I mentioned it to ever observed it before, nor did I observe it myself till lately.

Jurrecondah, 10th January, 1796.

This is not a rice country, but a Carnatic man, whose family practices the Drill Husbandry somewhere to the westward of Madras, informs me, that it is there used in the culture of rice, and is vastly superior to the method generally used of making a seed bed, and transplanting it by hand.

At the commencement of the rains, he says, the paddy-field, after being well ploughed with the common plough, is sown by the drill plough, and left to the natural rains till it gets into ear, and it is then, and not till then, flooded by art; so there is not only a great saving of labour, but of water, which in years when the rains are scanty, is a more material saving, than even that of labour.

He informed me, that the Drill Husbandry to the westward of Madras was only partially used, and that, chiefly by the wealthiest and most intelligent of the Ryots. I asked him, how it could happen that the poorer sort did not avail themselves of so obvious an advantage? He said that the people were poor and ignorant, and it could not be attempted by those who had less than three yoke of stout oxen, one for the Drill plough, another for the horizontal plough which follows, and allowance made for the accidental lameness and sickness of cattle; the weaker are not able in a miry soil, such as paddy-field, to draw the plough so straight as is required, and buffaloes are seldom so manageable as to plough very straight; these, said he, are the reasons why the Drill Husbandry is not more generally adopted in the culture of rice, for all agree in this, that it saves a great expense of labour and of water.

Every thing in this district, except horse-grain, is cultivated by the Drill Husbandry; I may mention hemp in addition to the articles I before enumerated. Of its superiority in the culture of cotton, I had a convincing proof the other day, when I saw more weeds cut up by the mamoty plough before described, in an hour, than could have been done by hand by many coolies, in a whole day.

This cotton was of a dwarf species, and sown by the Drill plough; I saw another field of a different kind, the drills about thirty inches asunder; this I understand was sown by hand; the drills were made by the common plough. In the same way is sown the castor-oil seed, the drills about a yard asunder; in short, the Drill Husbandry is practiced by every Ryot in this district, without a single exception.

XIV

IRON WORKS AT RAMANAKAPETTAH

(By Dr. Benjamin Heyne (1st September 1795).)

Owing to that natural impulse which I feel of attending closely to such objects as have once been voluntarily taken in hand my mind has frequently recurred to my last report of the Letchemporam Iron Works; thinking that an attention to this branch of science, or rather Indian manufacture, may prove of essential benefit; which has induced me, to avail myself of the first opportunity that offered, of seeing works of the same kind, at other places; whilst I also entertained the hopes, of being thereby enabled to point out a place where works of that nature, of consequence, might be erected, with a full prospect of success, if it should be thought advisable to establish them in this country.

It so happened also that my excursion to the diamond mines of Mallavilly, proved favourable in this respect, for I learned on the road, that many places in the Noozeed Zemindary, furnished iron for common use; and the nearest place to the Mallavilly, was, for obvious reasons, preferred to others more distant. This was Ramanakapettah, a village 3 *coss* from Noozeed to the northward. The way to it from thence, is mostly through a jungle the greater part of which, lies, in the vicinity of some fine large tanks, from which in favourable seasons a very sufficient quantity of water might be furnished to produce a very plentiful harvest of paddy, were there hands enough for cultivation.

A great number of palmera trees growing in the thickest part of the jungle, sufficiently evince the existence of former villages and greater population.

The soil in the high ground, both cultivated, and uncultivated, mixed with gravel and clay, often of the kind which the Gentoos call Rawada, i.e. clay mixed with gravel.

Ramanakapettah, has much better buildings than Noozeed. The streets are very broad, and the houses, in the fashion of the natives, good and large. A Choultry, one of the best I have seen in the Circars is in the middle of the village, and a fine large tank near it, to the south affords one of the greatest comforts to the inhabitants. The nearest of the hills, are to the eastward; and forms a kind of amphitheatre, opening to the southward. In this lies the village and all the iron mines. Before the famine,(The reference is evidently to the famine of 1790-2 which reduced the population of the Noozeed Zemindary from 1,00,374 in 1786 to 57,865 at the end of 1793. (See report from Noozeed Committee: Proceedings, Madras Board of Revenue, 16.1.1794),—*Editor.*) there were besides 40 smelting furnaces, a great number of silver and copper smiths, here, who were in a state of affluence; but their survivors are now poor and in a wretched situation.

The iron mines are to the northward, a mile from the village and half a mile from the hills; from whence they bring the ore, in baskets, to the furnaces that are close to the village. In former times, they seem to have found the ore nearer to it. The smelters do not, here, as at Letchemporam, themselves, work in the mines, nor do they burn their coals, but rather buy both articles, the former in baskets from the mines and the latter from labourers who bring them from the hills.

The ore runs in beds or layers, immediately under the first stratum of the ground (which consists as before said of gravel and sand) and is scarcely one and a half foot in thickness. These layers are of a small extent, and of all dimensions; seldom broader than two feet, and from two to four in thickness. The ore is very easily worked, as it consists of small round stones, which are in no way connected. It by no means derives its fusibility from the admixture of chunam (or lime) as does that at Letchemporam. Neither is any addition of other earths used, in order to promote that quality. Although it does not partake of the nature of any of the common iron ores in Europe, it comes nearest, to the haematites. It has for its properties, that of sticking on its fracture to the lips, when moistened; and is of so fine a grain, that it admits of being made into a very fine powder, which seems slightly to effervesce with acids. It appears to have very little of a silicious admixture, except some stones that consist entirely of a silicious aggregate cemented together with occhreacious clay, but these the smelters pick out as useless. Having no lodestone I cannot say whether the iron in it is in a state attachable by it; but might I be allowed to guess, I think it must exist in a semi-reguline state, which I find to my great satisfaction is admitted by some learned mineralogists which is an opinion that I merely offered as my own in my report on the Letchemporam works.

Of the outward appearance of the mines I can say nothing, but that from a distance they bear, a striking resemblance to fox's holes. Their furnaces which were forty in number before the famine, are now reduced to ten, and are in no ways different from those of Letchemporam; nor does their mode of proceeding, differ in any essential degree.

The coals they use in common, are from Mimosa Sundra of Dr Roxburgh, (and Sandra of the Gentoos) which I am told grows on the nearest hills in abundance. They however find any other firm wood answer their purpose as well. Four gunny bags of coals is sold for one rupee and two annas, it is the quantity required for every smelting; For the ore, they pay one *Dubb* per basket, of which 12 are reckoned sufficient for one smelting; the ore is not reduced into smaller pieces, but thrown into the furnace just as it is dug up. The scorias are let out only twice, the last time just before they cease working the bellows.

With respect to the subsequent necessary addition of coal and ore, after the smelting is begun, and the first article consumed, they proceed more rationally than at Letchemporam; by discontinuing to throw these articles into the furnace, more than an hour before they remove the obtained metal.

The whole produce of 1 maund, is sold for 2 rupees after it has been heated and hammered, to separate the scoria with which it abounds. For its more ready disposal, they make it into small pieces, weighing 2 pounds. It is still however in a very crude state, but of a soft nature, and so the more easily applied to common purposes. There is a greater demand for it than they can possibly supply though the greatest part of the year they are employed in the smelting business.

There is no doubt, but that, this place will be found eminently deserving of notice, in the event of adopting any large works of this kind, in the Company's possessions. The ore can be procured in any quantity that is required, and probably at a less expense than anywhere else. The nearest hills afford wood for coals in plenty; and what is of still more consequence, there are many people who would be glad to be employed in a business, which, under their own contracted management, (The contracted management seems to have resulted from the disruption caused by the famine. The 'constant dread', the iron-makers lived under, mentioned by Dr Heyne in another account, 'lest they should be pressed for the purpose of carrying burdens for strangers [i.e., the British army and civil personnel] from one village to another, a thing which often happens in the very season when it is in their power to employ their time to most advantage to themselves', also seems to have added to such contracted management.—*Editor.*) has hitherto afforded but a scanty subsistence.

Every furnace requires at present, nine men, who are chiefly employed in working the bellows, an operation might be soon and easily improved by a proper mechanical apparatus, through the medium of fire or water, or both, by which the number of hands would be easily reduced.

Besides this village I am told there are six more in the Noozeed country and in which iron is constantly fabricated, of which however I do not as yet know any thing more than their names. But as soon as opportunities offer to me of examining these, or any other works of the same nature, I shall not fail to give the subject the best attention in my power; so as to enable me to furnish any further information which my limited knowledge may enable me to offer.

XV

THE MODE OF MANUFACTURING IRON IN CENTRAL INDIA

(By Major James Franklin, Bengal Army, F.R.S., M.R.A.S., (circa 1829).)

An opportunity afforded by the Government of Bengal in 1828-9, having enabled me to examine several iron mines in the central part of India, and to make experiments on the Indian mode of manufacturing iron, I beg to offer the result of my observations to the hon'ble court of directors of the East India Company and I desire more particularly to draw attention to the simple forge and refinery, by means of which the process of smelting and decarbonisation is performed.

These mines are situated in the districts of *Jabalpur, Baragaon, Panna, Katola,* and *Sagur*, in the bed of a great central channel, which intersects the heart of India; and their localities are as follows.

IRON MINES OF JABALPUR

In the district of Jabalpur the best mines are at *Aggeriya, Gatna, Baila, Magaila, Jowli, Imliya,* and *Baragaon*, and the ore (No.12) of the first four, is micaceous, resembling in its less oxidated condition Iron Glance; at *Aggeriya, Gatna* and *Baila* it is interstratified with *sandstone*, and exploited from a small hill capped with *laterite;*[1] but at the other places, it is in fragments, buried in ferruginous gravelly clay, about five or six feet below the surface; it melts easily; and on actual experiment, 170 sers of ore, smelted by 140 of charcoal, produced 70 sers of crude iron *en masset*, in ten hours, which is equal to 40 per cent; the ore of Magaila is less oxidated than the others; it slightly affects the needle when heated, and sometimes crystallises; its streak is cherry red, and from its hardness, it is principally smelted for steel.

The same kind of ore (No.13) still less oxidated, is in great abundance, interstratified with *quartz sandstone*, and forms mountain masses, exhibiting a variety or contortions, as in the Lori hills; in this state, it is shining, splendent, and even glittering, but it is never smelted, because there is better ore on the same spot.

The ore of *Jowli* (No.15) is the *ochrey* variety of red oxide, it is almost a pure oxide, and affords a good pigment; it soils the fingers deeply, and its stain on cloth is difficult to wash out; it melts more easily than the former, and on actual experiment 185 sers, smelted by 165 of charcoal, produced 77 sers of crude iron *en masset*, in something less than ten hours, which is nearly 42 per cent; it is associated with a compact variety, (No.16 and 17) which appears to contain *specular* ore, from the blood red colour reflected from its small crystals when fresh from the mine; it lies near the border of a range of trap hills, and is clearly a deposit, or a vein, in the fissure of a rock resembling *hornstone* (No.18) which has probably been thus changed by contact with the trap.

South of the river Nermada near the village of *Dangrai*, the micaceous variety (No.19) is found in thicker laminae, interstratified with *quartz sandstone*, which separates into rhomboids; it is extracted by breaking the rock, but its iron is bad, and as it scarcely repays the expense and labour, it is rarely smelted.

The general character of the ore of these mines appears to range in the class, which the Comte de Bournon denominates *fer oxyde au maximum*; the *micaceous* kind is at times so highly oxidated, that it is nearly pulverulent, and the *ochrey* variety is almost a pure oxide; the compact species is rare, and fibrous *hematite* (No.19) is still more scarce; in every instance it is found near the surface, and all the varieties, except that of Magaila, yield excellent malleable iron.

IRON MINES OF BARAGAON, LAMTERA & EMLIYA

The mines of *Baragaon, Lamtera* and *Emliya* in the pergunnah of Belhari, are situated on the north side of the valley, and it is remarkable that near this ridge, there is a change in the nature of the ore; it lies near the surface embedded in ferruginous sandy clay, and is unconnected with any rock, though the subjacent stratum is *sandstone*; in the two first of these mines, the ore is granular, argillaceous (No.20) in globular grains, about the size of a pea, which are cemented together into a solid mass, by ferruginous clay; the other is the lenticular variety of the same kind of ore (No.21) differing from the former in the size and flatness of its pieces; but its cement is of the same nature, only less hard, and the nodules of ore being more easily separated, appears to give it a superiority over that of *Baragaon*, the grains of which not being divisible, its ore is perhaps affected by some vitiating property contained in the cement, the metal being very brittle.

IRON MINES OF THE DISTRICT OF PANNA

The best mines of the Panna district are near Brijpur, the ore is common argillaceous lying in a thin stratum, between beds of *reddle* and yellow earth (No.22) the former below, and the other above it; both these earths adhere slightly to the tongue, and fall to pieces in water, but do not form a paste, the former dissolves rapidly, the latter after a slight ebullition falls first in flakes, and finally into powder; on calcination the yellow earth assumes a lively colour—like English red, and they both would form useful pigments; the ore yields bad and brittle iron; but there is another kind of red ore exploited and smelted at the village of *Simmeriya* which produces better metal.

IRON MINES OF THE DISTRICT OF KATOLA

The district of *Panna* produces diamonds, and the tract in which they are found, borders on the iron mines of Katola; the Ken river being the boundary between them; and though this circumstance is foreign to my present object, it is at least curious, as it may perhaps serve to show, the connection, between the gem and ferruginous matter: the iron mines of Katola are in a cluster[2] of hills which extend between the Ken and Dessan rivers, and the ore, with one exception only, consists of varieties of the red oxide, its changes being from the most compact form, having a metallic lustre, into common argillaceous, according to the quantum of clay, associated with it; the nature of which will be best understood from the specimens which are sent herewith.

Commencing from the *Ken* river and proceeding westward, the first mine is in the *Pandua hill* (No.23) but as it is nearly exhausted, I pass on to those of *Amrownia*, *Majgaon*, and *Motehi*; the ore of the first and second of these places (No.24) resembles that of *Deora* to be described hereafter, and that of the third (No.25) is in the form of water worn pebbles of various sizes, which are embedded in ferruginous sandy clay; the mines are situated near the foot of the Bindachel hills which are here composed of *sandstone conglomerate*, and capped with the newer horizontal *sandstone*, which everywhere is uppermost in this range; the iron stone pebbles are about fifteen feet below the surface, and are intermixed with blocks, and fragments of *sandstone*, the whole bearing evident marks of attrition; the metal made from them is not esteemed.

Next in succession still proceeding westward, are the mines of *Deora*, the ore of which (No.26) is of two kinds, one compact with a metallic lustre, and the other containing a large portion of clay; the second of these is found high up in the hills, and in a vein, or deposit, immediately below the upper *sandstone*; it yields very good malleable iron, not brittle like that of *Motehi*, but such as may be drawn into thin plates without bursting.

About five miles farther west are the mines of Kotah, but the iron is bad, and I therefore pass on to the more celebrated mines of this district, viz. those of *Saigerh* and *Chandrapura*, which are situated on the crest of the *Bindachel* range, and near the point where the waters separate; in this respect they correspond with the mines of *Baragaon* and *Emliya* before mentioned, and like them also, the ore (No.27 and 28) differs both in nature and character, from all the other ores of this district; it lies in a thin vein, in ferruginous sandy, or gravelly clay—very near the surface; and its streak, in some specimens is yellow, in others yellowish brown, whilst that of all the other ores is red; in general appearance, it somewhat resembles the ore of *Baragaon*, but the grains are not so perfectly formed; its iron is excellent, possessing tenacity and malleability in a high degree far excelling every other description of iron produced in this district; *coal shale* crops out in its neighbourhood, and in all probability *coal* exists near the mines, but with all these advantages, the want of water carriage will ever prevent them from becoming more valuable than they now are.

West of the above, are the mines of *Piperiya, Rejkoi* and *Kanjra*, the ore of the former (No.29) is something like that of *Saigerh*, and is usually mixed with the other two, to correct them; that of *Rejkoi* (No.30) being nearly compact, and that of *Kanjra* (No.31) containing more argile.

Next in succession, still proceeding westward, is the *Chapar* hills near the town of *Bajna* which abounds in iron, and viewed at a distance it appears as if blackened by fire; its base is surrounded by protrusions of greenstone, and its stratification appeared to me to exhibit marks of derangement; at the foot of it is a cavern, and a chasm, filled with water to the depth of 220 feet, and an isolated fragment in its neighbourhood seems to have been separated from its parent mountain by violence; these appearances are very striking, and furnish grounds for speculation, but my present business is with its mines, which are situated at *Bajna, Keritanga,* and *Suka*, near to *Surajpura*; the ore of all which is nearly compact; the former (No.32) is on the summit of the hill, in large amorphous masses, the ore appearing to have penetrated the *sandstone* rock from a fissure of which it is excavated; the second (No.33) is a vein, in Syenite about half way up the hill, and the third (No.34) is in a small adjoining colline; there are some rounded pebbles of iron stone—dug out of ferruginous clay near the village of *Bhojpura*—but they closely resemble those of Motehi and deserve no further notice.

The last of the mines of this district are at *Serwa, Hirapur, Tighora,* and *Mandewra*, the former of which is in a small colline near the village, and the ore (No.35) does not appear to deserve notice; that of the latter (No.36) is of the same kind; but the ore of Hirapur is rich, and its iron in great request; it is also cheaper, and being situated on a good road it is often purchased in its crude state, and carried elsewhere to refine.

There are other iron mines still further west which are situated in a similar cluster of hills between the Dessan and Jamni rivers, as at Weldana, Sarai, Dhori Sagar & c.—and towards the north-west iron abounds in every part of the hills from the mines of Katola to those of Gualior.

The Katola mines extend from the Ken to the Dessan rivers, and it is remarkable that the ore is confined to the cluster of hills, which lie between those points—never being found northwards of them—and only in a few instances, in the *sandstone* range south of them; this cluster, like the detached hills of *Callinger* and *Adjyegerh*, have all the appearance of having once formed part of the great range; their bases are all composed of Syenite or Syenitic Granite, and their caps of *sandstone*, and there is strong reason to conclude that the iron ore, here found, is an associate of the latter rock;—with one exception only—it consists, as I have stated above, of varieties of the red oxide, and in no instance have I found it affect the needle, unless it is heated, and even in that case, it is the compact variety alone, which does affect it slightly; its principal vitiating constituent is clay—which the native smelters do not manage well—and this perhaps is the reason of their obtaining so little produce; the refiners also have *bad usages* in their refining process in common with other parts of India, and though it cannot be said that they are unable to make good iron if they please, yet it is a fact that they have an objection to make it good for bazaar sale, except in the shape of culinary or other utensils which yield a better profit; their furnaces both large and small, and also their refineries, are exactly the same as those of *Tendukaira* in form, and the only difference in their process consists in keeping the wind tubes separate, as at Jabalpur.

IRON MINES OF THE SAGAR DISTRICT

From the *Katola* mines, I shall proceed up the *Hirapur* pass and ascend the tableland, which being entirely composed of *sandstone*, and *trap* rocks, is not rich in iron ore; there are however a few spots where it is found in the Sagur district, but as it is not wrought in any part, to an extent sufficient to attract notice, I pass on to the mines of Tendukaira.

TENDUKAIRA

The Tendukaira mines are situated in a more westwardly position of the same valley, as those of Jabalpur, and are about one mile and a half distant from the village Tendukaira; they are near a low range of hills composed of *stratified quartz rock* which evidently contains felspar, and this rock is the gangue (No. 1) of the ore; at times it assumes the character of *hornstone*, and when contiguous to the ore, it is penetrated by numerous slender veins, which although filled with the oxide of iron are very different from ordinary dendritic appearances, as they are always in shoots, intersecting each other, and never arborescent, and it seems quite impossible that they could have been produced by infiltration.

The ore is never found near the surface as at *Jabalpur* but always about 30 feet below it, and in large masses, or beds, in cavities between the strata of the rock, which in some cases seems to have sustained violence; it is the brown *hydro-oxide*, both fibrous, and compact; but the former is by far the most prevailing; its general character, and appearance is opaque, and earthy, but when it has a metallic lustre, its fibres are beautifully fine, and constantly radiated; its most common form is irregular concentric lamellar, the lamellae of which are separated by a different colour, usually yellow, or yellowish brown; it is sometimes, though very rarely, crystallised, sometimes also it is mamillary and *botryoidal* but I have not met with any other imitative form; it contains manganese and silex, but sulphur is its principal vitiating constituent; its produce will be shown hereafter; but here it may be observed, that it yields most excellent malleable iron, fit for all uses, and also steel at nearly the same price as iron; there are five distinguishing names for it, which I shall give in the terms used by the native miners annexing thereto—their European synonyms: Gulkoo (No.2) includes all the waterworn pebbles which are embedded in diluvial gravel between the alluvium and the rock, under which the ore lies; it is a mixed and bad kind of ore.

Surma (No.4) is distinguished by its red appearance and is usually found mixed with the above, it perhaps contains arsenic and is always carefully picked out, and thrown away; *Peera* (No.3) or yellow ore, is the yellowish brown variety—always intermixed with the other kinds, and marking by its difference of colour their concentric lamellar form, it rarely occurs separate, its streak is yellow.

Kala (No.5) or black ore, is the compact earthy brown oxide, always dark coloured, generally approaching to black, sometimes but very rarely metallic (No.6) and crystallised (No.7), its streak is brown, and it is a very good kind of ore; *Devi Sahi* (No.8) or variegated, is the concentric lamellar variety (No.10 and 11) streaked with the yellow oxide; it has a fibrous tendency though opaque, but sometimes it is metallic as *Hemate* (No.9), and in this case its fibres are extremely fine, and of a silky lustre, its streak is yellowish brown and it is reckoned the best kind of ore, producing most abundantly, good malleable iron, and also tolerably good steel.

CHARCOAL

Charcoal is universally used in India for smelting iron, as the natives have no knowledge of coal, nor could they use it with their present refineries, because they are totally inadequate to the reduction of highly carbonised metal; they are fully aware of the effect of certain kinds of wood on the quality of iron and know from experience those which are best suited for their purpose; but as they cannot always obtain the trees they prefer—they use a mixture for their smelting process, excluding only such as are notoriously pernicious; but in their refineries they use exclusively *teak, mowa,* or *bamboo*, to the last of which they give the preference; in their preparation of it, they are expert from habit and no men are able to make better charcoal; they usually allow a month for drying the wood after felling, and their method of piling it, for burning, is in conical heaps; the remainder of the process being exactly similar to the practice of Europe.

FURNACES

Their smelting furnaces, though crude in appearance, are nevertheless very exact in their interior proportions, and it has often surprised me to see men who are unquestionably ignorant of their principle, construct them with precision, in so simple a manner; their unit of measure is the breadth of a middle sized man's finger; 24 of which constitute their large and 20 their small cubit; thus there is a constant ratio of 6 to 5 prevailing throughout these furnaces, nor is it of the least consequence, that their dimensions are larger or smaller, so long as all the parts are in the same proportion; the length of these measures is on an average 19.20 English inches for the large cubit, and 16 English inches for the small one.

As they have no standard measure their fingers, their span, and their arm are substituted by which a piece of stick is measured which they use in practice; neither is the division of the cubit necessary though the large one is supposed to be divided into six parts and the small one into five, of four fingers each—as the measurement is invariably ascertained by their fingers; the length of these parts is on an average 3.20 English inches.

Geometrical Construction of the Furnace

To construct the outlines of the furnace geometrically (Diagram I: fig 1 and 2) rule an indefinite line A.B. which suppose equal to a large cubit of 24 digits or 19.20 English inches, and divide it into 6 parts; at C erect a perpendicular, then from C to E set off 6 parts and it will mark the central point of the greatest bulge, and consequently the point of greatest heat; next, from E to F set off 6 more points, and it will mark the point of cremation; then again from F to G, 6 parts more, will mark the line, where it is necessary to recharge the furnace, after the burden has sunk thus low, and from G to D—two parts more; will give the perpendicular height of the furnace, in 20 parts equal to 5 feet 4 inches of English measure.

To complete the figure, rule lines parallel to the base, through the points E, F, G, and D, and from D, fig 1, set off three parts to the left hand for the top; bisect it at J, bisect also the bottom at H, draw H, J, right angled at K, and it will be the oblique axis of the furnace (fig 1. K—J) bisecting all the parallels corresponding with CD (fig 2)—then make the parallels AB six parts,—E six parts, F five parts, and D three parts; rule lines through all these points, and the geometrical outline will be completed, the sum of the parallels in parts, corresponding with those of the perpendicular.

Practical Construction of the Furnace

To construct it practically—dig a fosse 3 feet deep in the annexed form (Diagram 3, fig 2) the semicircular part of which contains the furnace B, the walls CCC being composed of unburnt bricks of large dimensions; the first structure is crude, preserving only an approximation to the required form, the interior being afterwards cut away; a large stone capable of containing heat is placed at the bottom; and in this state it is suffered to remain until thoroughly dry; the next operation is performed by a more skilful artist who cuts away the interior, and plasters it with clay, using the measures above described to adjust its dimensions; he first finishes the top, and from the centre of the back part of it, he drops a plummet, to ascertain the spot where the centre of the front part of the stone is to rest; this plummet line corresponds with the perpendicular CD of the geometrical figures 1 and 2—and thus he obtains not only the required obliquity of the furnace, but the points most essential for the adjustment of all the rest.

When the furnace is thus far prepared it is again suffered to dry, and in the mean-time, other appendages called by the Indian smelters *Gudaira, Pachar, Garrairi*, and *Akaira* (names which have no synonyms in the English language), are constructed; the Akaira in particular is a most extraordinary implement, (Diagram I, figs 4 and 5; and Diagram 2, fig 1+); externally viewed it is a clumsy mass of clay enveloping the wind tubes (Diagram I, fig 9) but when it is considered that the complete fusion of this mass, and the perfect completion of the smelting process must be simultaneous results, the implement becomes the most important of all the appendages; thus for instance if it is too small, or too large, its effect will immediately be perceived; in the former case the masset of crude iron will be full of impurity, and in the latter the iron will be consumed, and if it cracks during the operation of smelting, there is no remedy for such an accident—short of dismantling the furnace and commencing the work again.

I found after numerous experiments that its mean length should be 4½ parts, its mean breadth 3 parts, and its mean thickness 1½ parts and it is somewhat remarkable that the product of these dimensions, should exactly equal a twentieth part of the cubic contents of the furnace when fitted for use; this coincidence may arise from the peculiar nature of the clay of

Tendukaira,[3] the ingredients of which are well assorted, but the rule will nevertheless apply generally—because clay by admixture is susceptible of being rendered amenable to rule; and therefore this implement will be found in all Indian furnaces to have (or by tempering the clay may be made to have) the same corresponding dimensions.

The Guddaira is a wedge of clay used to adjust the vertical position of the Akaira when placed in the furnace; and the Pachar is an oblong plate of clay, used in walling up the orifice after the Akaira is placed, and adjusted; these figures and dimensions are given in Diagram I—fig 7 and 8; the Gurairy (Diagram I, fig 6) is a convex plate of clay; perforated with holes and used as a grate—through which the scoria are drawn off.

When the appendages are ready, and the furnace thoroughly dry, it is prepared for use in the following manner.

The front part is walled up from the top to the line SS—Akaira to the top (Diagram I, fig 1 and 3) which line is ascertained by the small cubit; one end being placed at C, the other will measure CB and CS (fig 1)—the grate is next put in, its lower edge resting upon the edge of the stone; and the space is filled—with a mixture of pulverised cow dung and Kodo straw—up to the dotted line (Diagram I, fig 1) upon which is placed the Akaira; its sides being every where 1½ parts distant from the walls of the furnace—as represented in Diagram I—fig 4 and Diagram II—fig 1+; where a, b, c, d, are the walls of the furnace, fig. 5 and 1+ the Akaira; the Gudaira[4] or wedge, is next introduced in order to adjust its vertical angle (Diagram I, fig 1) and this being placed satisfactorily, the Pachar is inserted and the whole has then the appearance represented in Diagram I, fig 3, where No.5, 6, 7 and 8, are the Akaira, Gudaira, Pachar, and Garrairi; nothing now remains but to lute the whole with clay, leaving the ends of the wind tubes open to receive the bellows.

Bellows

The bellows are as singular in their construction as the Akaira, and are worked by the hand; they are made of a single goat skin, the dimensions of which ought to be 7 parts in breadth when doubled, and 8 parts in length; such proportions being required for circular bellows of 5 parts diameter, and which when worked by a man of ordinary strength will rise 6 parts in height—having 11¼ circular folds; the wooden nozzle through which the

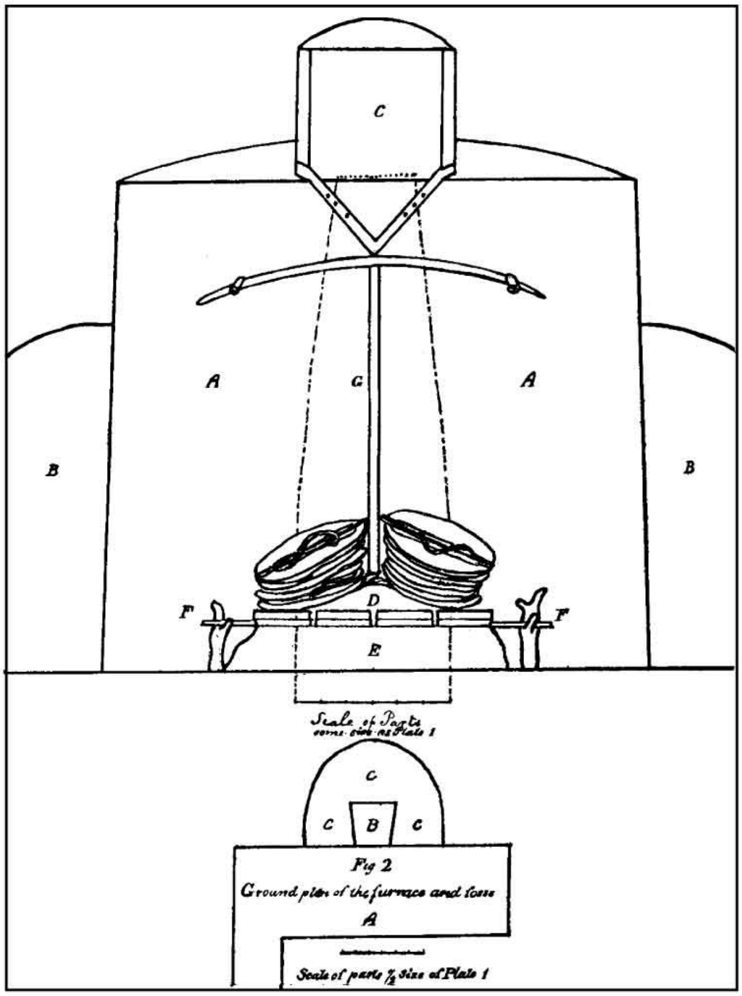

DIAGRAM III

blast is conveyed into the furnace surfaces the Akaira in its complex nature, and so little is its principle understood—that the art of making it was once lost at *Tendukaira*, and was again restored by the smelters of *Katola*.

Construction of the Nozzle of the Bellows

To construct its figure geometrically, rule a line AB equal 3 parts (Diagram II, fig 2) divide it into four, giving one of those divisions to each of the legs, and two for the space in the centre; set off a perpendicular from C to D equal 3 parts; bisect it and the middle point will mark the apex of the central angle; then through the point D rule a line parallel to AB and from it as a centre set off each way ¾ of a part making together 1½ parts; divide it also into four, giving one of each to the legs, and two for the space in the centre as before; and then by ruling lines to connect all these points, the outline will be complete; the exterior of the implement is plain but the interior is complex and cannot be described except by a reference to Diagram II: fig 3 which represents it, divided in the middle, to show its internal structure.

This curious appendage is fastened to the bellows by leathern thongs, and the blast is forced through it at an angle of 24 degrees but when it is luted to the wind tubes of the Akaira, the blast enters the furnace at an angle of 12 degrees, both vertically[5] and horizontally—because those tubes are placed so as to reduce that angle; Diagram II, fig 1+ represents the whole apparatus luted together and placed in the furnace the walls of which are marked a, b, c, d, and it exhibits at one view, the whole of the mechanism of this complex machinery; the furnace when closed up with clay, and the bellows luted in, is represented entire in Diagram III and IV; the dotted lines showing the chimney—A the outer walls, B, a mound of earth to strengthen the walls, C an upper chimney of moveable bricks, D planks laid across the trench to support the bellows and the man who works them, E a stone supporting one end of the plank, F forked branches supporting an iron bar on which the other end of the planks rests, and G a simple apparatus for preventing the bellows from rising from the planks when they are worked.

The above description is not founded on theoretical conclusions; the measurements given are derived from taking the mean of several and the results were proved in furnaces under my own superintendence; the coincidences of the several parts are very striking, thus for instance, the perpendicular and parallel lines of the geometrical outline are equal in quantity (Diagram I, fig 2); and the top, bulge and bottom being 3, 6, and 4½ parts respectively, show that the furnace is exactly constructed, and that it corresponds well enough with the most regular furnaces of Europe (Diagram I, fig 1); it is also curious, though perhaps of no importance to observe, that the mean of those numbers, being squared and multiplied by the terms of the perpendicular or axis, give the cubic area of the furnace, and show that it is twenty times larger than the cubic content, of the Akaira; the angle of the blast is also worthy of notice, as well as the simplicity by which both it and the obliquity of the furnace is obtained; all these serve to show that the original plan of this singular furnace must have been the work of advanced intelligence, and that its geometrical proportions have been preserved by simple measures; hence though its original form may be changed by caprice or ignorance, its principle never can be lost so long as hands and fingers remain.

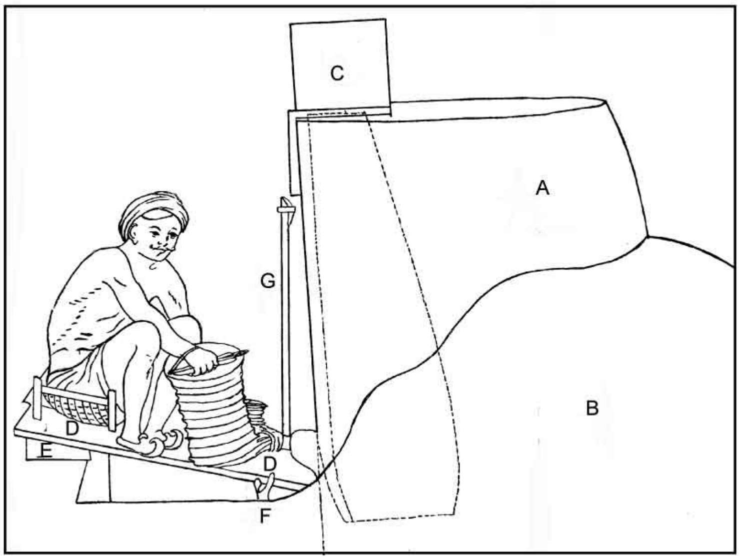

DIAGRAM IV

REFINERIES

The refinery is as crude in its appearance, and as novel in its construction as the furnace, to which it seems to have been purposely adapted: two refineries being required for one smelting furnace; to construct it they use the small cubit of 20 digits, or what is still more available, the space or distance between the tips of the thumb and little finger of a middle sized man when extended without force, two such spans being considered equal to the cubit; the first process is to arrange a number of square unburnt bricks, as in the ground plan (Diagram V, fig 1) in which a, a, a, a, are the walls—A is the chimney, B the refining furnace, C the seat of the refiner, and D the anvil; see also fig 2 for a side view of it—divided in the middle for the purpose of showing the interior structure, in which E is a piece of crude iron under the process of decarbonisation; the dimensions of the chimney are not material—but it is usually about one cubit broad, one deep and six in length; the oval part where the operator sits is altogether a fanciful appendage, being merely a mound of earth in which a log of wood is inserted for receiving the anvil—and its elevation serves the further purpose of giving the workmen a purchase in using the hammer; when the walls of the chimney are finished, the top is covered with unburnt bricks of an oval shape, flat below and convex above and these are luted together by a plastering of clay—fig. 3 is a front view—showing the opening of the furnace and Diagram VI exhibits the refinery complete, with the refiner at work on his seat, the bellows-man plying the bellows, and various implements lying about—A the outside of the chimney—B a mound of earth to strengthen its wall—C the refining furnace—D a piece of crude iron undergoing the process of decarbonisation (in dotted lines) —E the bellows-man plying the bellows—F the refiner with an iron spike in his hand regulating the operation (the dotted lines showing the interior of the furnace)—G a thick plate of iron placed at the bottom of the refinery (in dotted lines)—H a fosse for the hammerman—I the anvil—K implements, and L a heap of charcoal.

The furnace of the refinery is the only part which requires skill in its construction, and this is usually done by the operator himself; its geometrical outline is represented (Diagram V, fig 4) and its construction is as follows. Rule a line AB equal five parts, divide it into six—set off four of these divisions for the top—let fall a perpendicular from the centre C—set off three divisions from C to D for the depth—rule a line through D—parallel to AB and make it two divisions, now rule the outline—bisect the perpendicular and the centre parallel will be equal to three divisions.

The centre parallel is the most important part of the furnace and next to it is the accurate adjustment of the angle of the blast; I have frequently seen the Indian refiners obliged to discontinue their work on account of some error in this point; the usual measure for the former is the span above mentioned

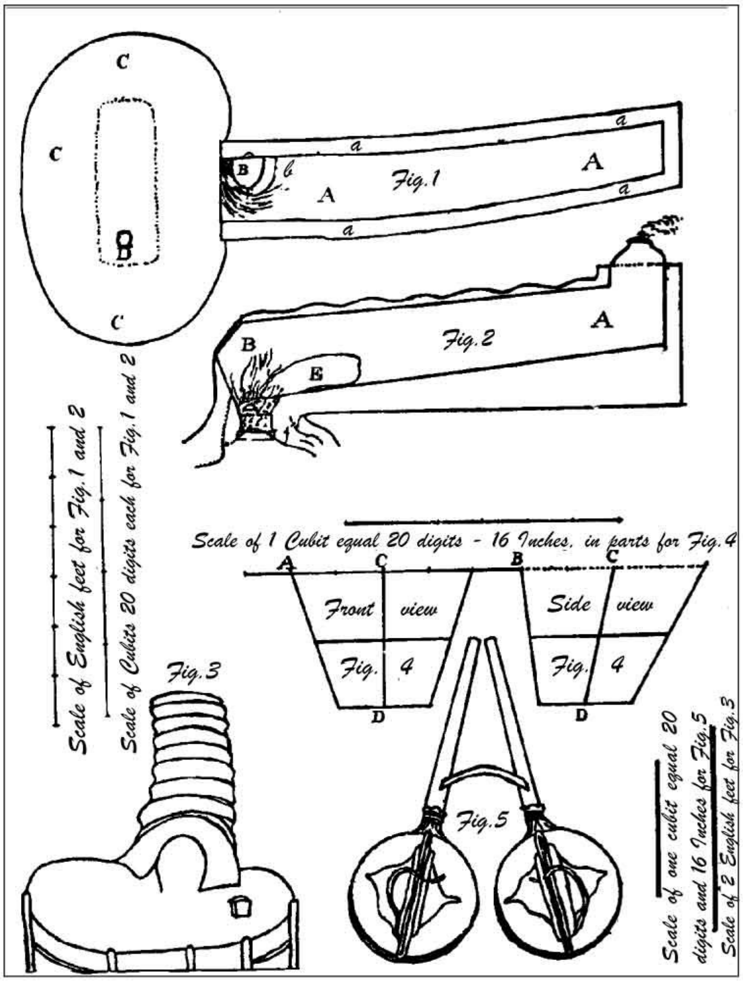

DIAGRAM V

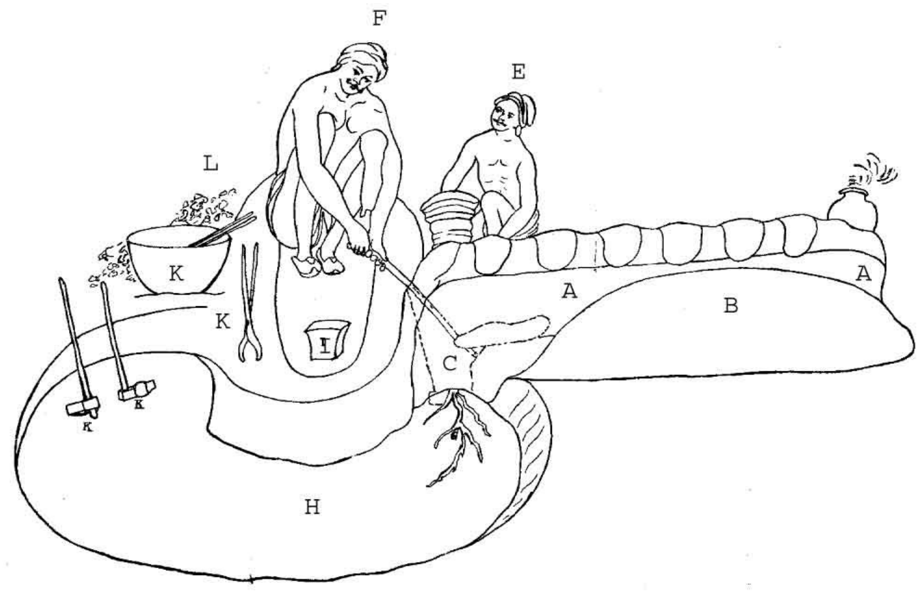

DIAGRAM VI

applied both longitudinally and transversely as in Diagram V, fig 1, B where a ground plan of the furnace is exhibited—the inner circle of which corresponds with the centre parallel of fig 4—this measure never differs much from 8 inches, and that quantity may be assumed as a fair average;—the outer circle *b* of the same figure is indefinite—the space between the two—being merely a slope, chamfering from the inner edge, and gradually expanding, until it is lost in the sides of the furnace, so that in fact it is reverberatory; with regard to the blast, it is absolutely necessary that it should be directed, at an angle of about 12 degrees, upon the opposite edge of the inner circle or to the point c fig 1, B; the natives have no instruments to enable them to do this exactly but the working of the furnace soon tells them where there is an error and they know well enough how to correct it;—the bellows resemble those of the smelting furnace, but instead of the wooden nozzle, they are furnished with long iron tubes—as in Diagram V, fig 5 which are so placed, that the angle of the blast thrown through them is 24 degrees, the same as that of the wooden nozzle.

SMELTING FURNACE

Diagram VII: fig 1 and 2 represent the front and back view of a small circular smelting furnace, which is very common in India —its measurement may be taken from the scale of the diagram either in parts or inches; the bellows are the same as fig 5: Diagram V, and the form of the interior or chimney is exhibited by dotted lines; fig 3 and 4 of the same diagram show another description of refinery used chiefly for decarbonising large masses for the manufacture of anvils & c. worked by two pairs of bellows—this refinery might be more extensively applied; such as for the manufacture of adletress* or other heavy work.[6] Fig 5 is a small field blacksmith's forge, constructed of the same kind of oval bricks, as those which are used for covering in the refinery, and luted together by clay; this apparatus may be constructed in half an hour; and is a useful field-smithy; fig 6 is a tube of clay, used in the refinery to preserve the ends of the bellows—fig 7 is a tube of the same kind used in the small circular furnaces.

MODE OF SMELTING AND REFINING

In the process of their manufacture the Indian smelters use charcoal only; the ore is broken into pieces about the size of a walnut, but it is not washed, nor is it roasted although it is known to contain a large quantity of sulphur which might be dissipated by that method; they commence by filling the chimney of the furnace

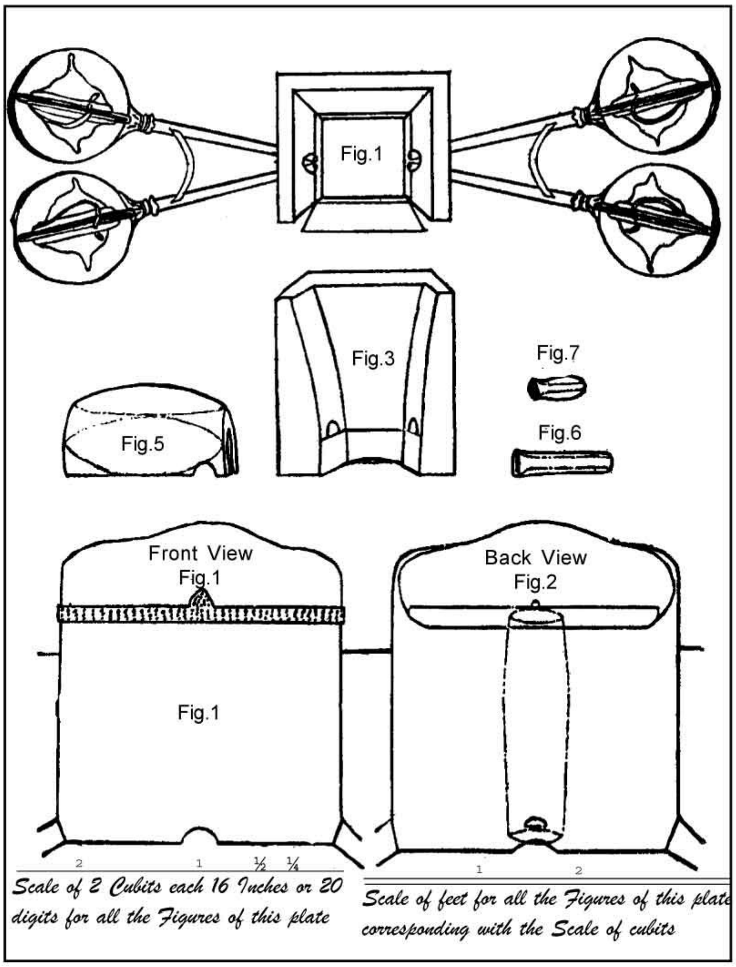

DIAGRAM VII

with charcoal which they suffer to burn until all moisture is expelled; they then throw in a small basket of ore, and upon it a larger one of charcoal, after which the burden is allowed to sink as low as the line G (Diagram I, fig 1 and 2) when it is again charged—and afterwards ore and charcoal are alternately given in the same proportions until the operation is complete; the scoria begin to flow within the space of an hour, and by that time, it is known whether the furnace will work well or ill—the scoria being a sure indication; it is let out by piercing the grate with an iron spike, and the orifice is again closed with clay as soon as it is drawn off; the bellows are worked by three men—who take it by turns; and they should be kept constantly playing until the process is completed; the time of which is ascertained by introducing a hooked piece of iron through the wind tubes, into the furnace, which shows how much of the Akaira remains; for as I have shown before, it is indispensably necessary that this appendage should be totally fused before the operation is complete, and when this is the case, it would be useless to continue longer, because the furnace would cease to work properly; it usually continues 12 hours but much depends on the bellows-man, and also on the working of the furnace.

The metal is never completely melted by this process—the heterogeneous mixture of the ore alone is fused and thrown off in scoria, and the iron being freed from it falls by its superior gravity to the bottom of the furnace, and there coagulates into a mass or masset; it is never very highly carbonised, and sometimes it is partially malleable even in its crude state; when the process is finished, the bellows are removed; the front part of the furnace demolished; and the red hot masset dragged out, and divided by large ades* before it has time to cool, hence it happens that the parts of the furnace thus broken up, require daily renewal.

This completes the business of the smelting furnace—the process of decarbonisation being performed in the refinery, and Diagram VI: fig. D, represents half a masset—properly placed in a refinery and undergoing that operation; as it becomes decarbonised, it drops into the hollow of the furnace upon the plate of iron G—and when a sufficient quantity has accumulated, it is taken out and hammered into more circular lumps which are seen in every bazar; the charcoal used in the operation is always of hard wood, such as teak (tectona grandis), mowa (fana latifolia)* or bamboo; this is the part of the manufacture in which the Indian manufacturers play tricks; for in the first place they do not allow time for the crude mass to become properly decarbonised and then again they have a most pernicious practice of knocking off corners and small pieces from the masset in its crude state into the decarbonising fluid, and instead of waiting patiently until the whole of the masset is decarbonised they often throw in large lumps at the end of the process, mixing all these crude pieces with the other so that the cheat cannot be detected except on trial; thus they not only shorten the time of the operation, and thereby use less fuel, but contrive by this nefarious practice to sell a large portion of their crude iron at the same price as the malleable; they are also very sparing in their hammering lest they should force out too much of the Vitreous Oxide and thereby reduce the weight; so that upon the whole there seem to be causes which have justly affected the reputation of Indian iron—but as they are repairable errors, they ought rather to be placed to the account of the perversity of Indian habits—than arrayed against that fair repute to which the Indian metal under different management might lay claim.

PRODUCE

The produce of the ore of *Tendukaira* varied from 36 to 40 per cent—but as it was upon the whole nearer to 40 than 36—I am quite safe in fixing the average at 38 per cent; I tried by roasting the ore to obtain a greater quantity but without effect, neither was I satisfied with its result in another point of view, as will be shown hereafter; with regard to charcoal the consumption varied according to its quality—or, in accordance with the working of the furnace. The following diary contains a statement of the daily produce of four smelting furnaces, from which I assumed a mean, as a fair proof of their power of production. They were under my own superintendence from the 30th April to 6th June 1827 which is beyond all question the most unfavourable portion of the year for smelting iron, and the result therefore is the more enhanced in value.

From this statement it appears that each furnace yielded upon an average about 18½ *Panchseri*,[7] and that every hundred sers of crude metal yielded 63 sers of malleable iron; the total of the produce therefore is as follows: the ore yielded 38 per

DIARY

Date	Produce in Panchseri	Weight when rendered malleable (in Panchseri)	Remarks
April 30, 1827	19	12¼	On the 8th of May, an attempt was made to alter the dimensions of the Akaira, and had it escaped detection a few days longer it would have occasioned a failure; as it not only diminished the produce of the furnaces but the massets contained so much impurity that the produce of malleable iron became greater. The effect of the hot weather became very perceptible in June, and I found it expedient to discontinue smelting on the 7th of that month, but in order to satisfy myself that there was no trick in the diminution of produce, I gave ore and charcoal to the bellowsman to smelt for their own benefit; they tried their best to obtain as much as they could and they got 13, 14, 14¾ and 18—the mean of which is 15—about the same quantity as they got for me. I was, therefore, satisfied that the diminution of produce was owing to the heat of the weather alone as the thermometer ranged from 120° to 122° in the sun, and from 108° to 110° in the shade.
May 1 1827	19	12¾	
″ 2, ″	19½	12¼	
″ 3, ″	16½	10¼	
″ 4, ″	18¼	10¼	
″ 5, ″	17½	10¼	
″ 6, ″	18½	12	
″ 7, ″	16	10¼	
″ 8, ″	14¼	9	
″ 9, ″	18¼	11¼	
″ 10, ″	19½	12¾	
″ 11, ″	20½	13¼	
″ 12, ″	21½	14	
″ 13, ″	20	13	
″ 14, ″	21¾	12¾	
″ 15, ″	21½	14	
″ 16, ″	22	13	
″ 17, ″	21¾	13	
″ 18, ″	20½	12	
″ 19, ″	19	11	
″ 20, ″	19	12¼	
″ 21, ″	19¼	12¾	
″ 22, ″	19¾	12	
″ 23, ″	17½	11	
″ 24, ″	18¾	12¼	
″ 25, ″	22	12¼	
″ 26, ″	18	10¼	
″ 27, ″	17½	11	
″ 28, ″	17½	10¾	
″ 29, ″	20	12¾	
″ 30, ″	19¾	12	
″ 31, ″	17	11	
June 1, ″	17½	10	
″ 2, ″	15	9	
″ 3, ″	18½	11¾	
″ 4, ″	16¾	11	
″ 5, ″	14¾	9¾	
6, ″	15½	10	
Total of one furnace	709	447	
Total of 4 furnaces	2836	1788	or 354½ & 223½ Maunds

cent—the crude metal 63 per cent—and the malleable iron yielded 56 per cent when wrought up into bars fit for use in a suspension bridge—as will be shown in the following paragraph.

QUALITY OF THE IRON

The iron was made over to Captain Presgrave of the Sagar Mint (an officer very capable of judging with regard to its quality). He wrought it up into bars and rods for an iron suspension bridge on which he was then employed and the following is his report to understand which it is necessary to refer to the note below.[8]

> The first six marks, afford bar iron (as far as my knowledge allows me to judge) of most excellent quality, possessing all the desirable properties of malleability, ductility at different temperatures and of tenacity for all of which I think it cannot be surpassed by the best Swedish iron; the second description consisting of the three last numbers in the accompanying statement has produced very good bars, but in forging and working it up, the iron appears somewhat harder, probably from it still containing a portion of carbon; the different marks varied in yielding from 50 to 60¼ per cent in bars, the average from the whole being rather more than 55¾ per cent.

It is necessary to add that the bar iron mentioned above, is not[9] common bar iron—but highly wrought bars, for use in a suspension bridge; the hardness alluded to in the three last numbers, was evidently occasioned by the metal 'still retaining a portion of carbon', and it is worthy of remark that this quality was confined to those specimens, the ore of which had been roasted.[10]

COST OF THE IRON

The cost of the iron was as follows. The excavation of a mine cost 30-12 Nagpur or 25 Calcutta Sicca Rupees; the construction of four smelting furnaces, two refineries, and one small round furnace, cost 34-12 Nagpur or 30 Sicca Rupees; and the purchase of skins and manufacture of seven pairs of circular bellows cost 30-5 Nagpur or about 25 Sicca Rupees—total of outlay 80 Sicca Rupees; but as my experiment lasted only five weeks, and the above outlay was calculated to last a whole season, a portion of it only is chargeable to the cost of the above iron; the hammers, anvils and other implements of iron, not being perishable articles—are chargeable only for reasonable repairs; thus the proper proportion of outlay is 15 Rupees, and the expense[11] of working the furnace was 441-0 Nagpur or 375 Sicca Rupees, the total of cost therefore for 225 maunds of malleable iron was 390 Sicca Rupees, or one rupee 12 annas per maund.

The iron was weighed by the standard of Nagpur—the maund of which place is about 3 lbs avoirdupois less than the factory maund of Calcutta; hence its weight is about 71 lbs 10 ozs avoirdupois, and 31¼ Nagpur maunds are nearly equal to one English ton; the value of the Calcutta Sicca Rupee is usually reckoned at 2 shillings and hence the cost of a ton weight of malleable iron in English money was five pounds nine shillings, and five pence, or in round numbers—five pounds ten shillings.

CONCLUSION

It was my intention to have compared this little furnace with some of the minor furnaces of Europe—but as my knowledge of the latter must have been derived from books, I prefer giving facts derived from actual experiment, and leave the comparison to those who are better able to make it: the quantity of crude metal smelted in my four furnaces from the 30th April to the 6th June, was[12] 354½ maunds, and its cost was 304 Nagpur or 260 Calcutta Sicca Rupees—hence its cost per maund was 11¾ annas, or two pounds, six shillings per English ton—and the produce per week of four furnaces was 71 maunds or 2¼ English tons.

These data show the cost of the iron both in its crude and malleable state and Captain, now Colonel Presgrave's report gives the latter so fair a character that it may be useful to follow up that report by another obtained from the Calcutta Mint on some pieces of *Jowli* and *Ageriya* iron which were wrought up to the state of English bar iron—and submitted to trial—the substance of the report is as follows:

> A piece of the Jowli iron being broken showed about half the surface of a fine blue tough appearance, the other half had a very brittle appearance of a glassy white colour resembling what the smiths in England call cold-short; this

piece 1 inch broad and ¾ inch thick was put into a clam and a lever applied to it; it twisted with a fair resistance, and bore one revolution in 6 inches without showing a fracture; it was then warmed and a hole punched through it, which it bore in a way that would have been expected in a piece of good English iron and better than the general run of English iron purchased in the bazar would have borne it. An eye being turned at each end, the space of 10 inches long was drawn down to one third of an inch square, and dead weight scale fashion without the use of the lever applied and in the length of six inches it elongated:

1/10th	of an inch	with	3378	lbs
2/10th	“	“	3624	”
3/10th	“	“	4795	”
5/10th	“	“	5127	”

and drew itself to near a point and broke with 5246.

A piece of the Ageriya iron, on being broke, showed a small portion of its fracture light blue tough vein, the remainder silvery white, showing very fine particles, and was what the smiths in England would say had an inferior appearance, it was 1 inch broad by inch thick, and was twisted cold one revolution in 6 inches without showing a fracture and appeared to be much stronger (to the twist in proportion) than the above piece from Jowli, though much softer; it was then heated, and punched which it bore in a manner sufficient to give it the character of very fair average iron; an eye being then turned at each end, the space of ten inches long was drawn down to one third and dead weight scale fashion without the use of the lever, applied and in the length of six inches—it elongated 1/20 of an inch, with 4748 lbs, and made a square break with 5376 lbs.

Though the Ageriya piece gave no notice of its approaching failure, whilst suspending a weight; yet when brought to the bend, it showed itself possessed of the power of elongating, and bore more bend without showing a fracture than the piece of Jowli and stood the bend better than the general run of English iron purchased in the bazar.

The above statement was addressed to Captain Forbes, superintendent of the hon’ble Company’s steam engines and machinery, to whom I applied to obtain a trial and the experiments were all made by one of the most able and practical men of the Mint—named Thomas Pigg.

Having now exhausted all my information which was obtained from actual experiment and impartial trial and proof I shall conclude with the following remarks—viz: that the Indian forge is able to make crude metal, for two pounds six shillings, and good malleable iron for five pounds ten shillings per English ton; it is moreover susceptible of improvement; it requires but little outlay; it is portable; and may be transported from place to place, the implements being the only things necessary to carry; it may be erected in places which combine the advantages of proximity of ore and fuel and where other furnaces requiring a large supply of water cannot be set up—and it may be erected for temporary purposes and abandoned when the object is fulfilled without material loss, the furnaces being the only part which would be lost and their cost is about 6 shillings each.

The employment of so simple a forge in England would be absurd—but considering it an instrument adapted to the existing condition of the country where it is used—it assumes a different character—for such is the cheapness of labour and fuel that I question whether any other furnace would compete with it —and if by improvement it can be made capable of working on a larger scale; arsenal materials, materials for bridges and other heavy work—it certainly is an object worthy of attention, as a great saving of expense might be effected by its use.

Note

1. Laterite is a term given by Dr Buchanan to a species of iron clay very prevalent in India.

2. *Note*: See the map which accompanies this paper.
[Omitted here. —*Editor*].

3. *Note*: It may here be observed the nature of the clay is a material point with regard to this implement, and at Tendukaira it is well adapted, being near the great trap-range, and reposing on a mass of cretaceous limestone belonging to the trap family; in all probability therefore it contains a small portion of lime; a few small grains of wacke may also be observed in it and in addition to these *Kodo* straw being mixed with it the potash derived from these materials facilitates the fusion of its silex, whilst the lime renders it a fusible compound, the ingredients of which are well assorted, and seem to be well adapted for use. The native smelters once deserted these mines on account of some pique, but the quality of the clay brought them back again.

4. *Note*: The broad end 3½, the narrow end 2½, the mean of which is 3 parts. These dimensions do not greatly differ from those of the native smelters, on the contrary they are founded on the mean of all the measures I could procure—and the difference consists in their being regular and fixed while those of the natives are irregular and often governed by caprice.

5. *Note*: The vertical angle is obtained by means of the wedge the thickness of which is adapted to the angle of 12 degrees, and the horizontal angle is obtained by keeping the ends of the wind tubes a certain number of fingers breadth as under when embedded in the Akaira. These quantities never differ much.

6. *Note*: The refinery is convertible into a blacksmith's forge by taking out the iron plate and building up a wall in the middle so as to destroy the reverberating effect.

7. The furnaces all varied in their produce but the mean is 18½ Panchseri—a Panchseri is 5 sers—eight of which or 40 sers are equal to a maund.

8. *Note*: I tried all the descriptions of ore and made experiments on roasting it—the result of which could only be ascertained by making the iron; the first six marks constituted the bulk of the quantity submitted for trial, and their iron result may be safely taken as a fair average; the other three are the result of my experiments on roasting the ore—previous to smelting.

9. The common English bar iron yields about 70 per cent of such highly wrought bars.

10. *Note*: The roasting of iron ore, previous to smelting is supposed to repay with advantage, the additional expense it occasions; and the reason of its ill success with me I can only explain as follows: The furnaces of Europe are I believe in general perpendicular that is—the ore and fuel fall perpendicularly and consequently their descent is more rapid; but in India the furnaces are oblique, and the descent of ore and fuel more gradual and hence sufficient time is gained for dissipating sulphur, or other volatile ingredients before it reaches the point of greatest heat; this appears to be the fact as the chimneys of these furnaces are always coated with sulphur; it would seem also that the metal acquires more carbon under the effect of both operations than the Indian refinery, constituted as it now is, can dispose of—and hence the hardness of the last three marks as observed by Captain Presgrave.

11. *Statement of Expense*

6 Men for each Smelting Furnace or 24 for 4 furnaces from 30th April to 6th June, or 1¼ month at 4 Rs. each per mensem	120-0
Charcoal for the Furnace for the same period	134-0
For digging ore	14-2
Carriage of ore	15-5
Carriage of charcoal	14-9
Head-Man	6.0
Total Cost of Smelting	*304-0*
1 Lohar Mistry at 8 and five Lohars at 4 [Rs.] per mensem for each Refinery: this sum doubled for two and for a period of five weeks is	70-0
Teakwood Charcoal for the Refineries	63-0
Head-Man	
Total Cost of Refining	137-0
Total Cost of Smelting	304-0
Total Expense	441-0

12. *Note*: See Diary.

XVI

MANUFACTURE OF BAR IRON IN SOUTHERN INDIA

(*By Captain J. Campbell, Assistant Surveyor General, Madras Establishment. (A.D. 1842).)

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1. In the commerce between India and England, a source of deep injury to the former country arises from England having deprived her of the trade in cotton cloth, the manufacture of which was, but a few years ago, one of the most valuable and extensive of Indian products; while from no other having been as yet introduced as an export to balance the imports from England, it has become necessary to drain India of her specie to pay the expenses of the Government, and for the articles she requires from the mother country. The Government both in England and in India have therefore been unremitting in their endeavours to promote and foster the export trade from India; and in the mean time have endeavoured to economise by means of the internal productive resources of the country, and thus in some measure reduce the export of specie, and at the same time disseminate a knowledge of practical manufacturing processes.

2. Among the most extensive of the exports of England to India, is the trade of bar iron, which to Madras alone amounts to 1,000 tons per annum; and while India is known to produce malleable iron of a superior quality, it has been frequently proposed as a question whether she could not supply her own wants in this article at a cheaper rate than if procured from England, if improved processes were introduced in the reduction of the native ores. I am not aware that any satisfactory experimental investigation of this point has ever been instituted, or given to the public; but from the remarks in the reports of the Committee for investigating the coal and mineral resources of India, it would seem that little or nothing is as yet known upon the subject.

3. English iron is not used inland in Southern India, in consequence of the great expense of land carriage, and from the same cause, it is probable, that in Northern India also, the only

iron used is that made upon the spot; and as the manufacture must be very limited in quantity ('quality' in original; appears to be a misprint.—*Editor.*), it becomes of much importance, both to individuals and to the Government, to be acquainted with the mode of supplying any extraordinary demand. Indeed, we are informed by Captain Drummond, in the Journal of the Asiatic Society of Bengal, that the carriage of a suspension bridge erected in Kernnon, alone cost about 80 rupees per ton, or as much as the iron might have been made for upon the spot.

4. In projecting the establishment of a new manufacture, persons are but too prone to copy an old established process, without studying sufficiently the principles by which the result is produced, so as to be able to modify the mode of operation to suit the resources of the locality, and the capabilities of the workmen; and because the English mode of manufacturing iron has been found to be the most profitable in England, it has been supposed that a similar process could alone answer in India. This process has also been styled 'scientific', but the fact is, that the principles of the mode of operation are still totally unknown, and the manufactures are not only unable to produce at pleasure a certain result, but even the quantities of the results produced depend upon the weather, and other causes as yet not explained, or beyond the control of the workmen. We do not as yet even know what cast iron is; nor with any certainty what its component parts are; nor in what it differs from steel, or the varieties of what are generally called carburets of iron. On this point Barlow remarks: (Encyclopedia Metropolitana) 'There is certainly much to be learned in the iron trade, before we can boast of any thing like a complete knowledge of its different processes. We observe many facts in this, as well as in other branches of the manufacture, of which, the most we can say is, that they are connected with, or caused by certain other accompanying facts, though we are ignorant how this connection exists; often, indeed, our knowledge does not extend so far.' Again, 'it is, however, so difficult to follow up chemical analysis, and to obtain results with minute accuracy, in a process requiring intense heat, that hitherto the phenomena attendant upon the refining of pig iron, and its conversion into bars, may be said rather to be guessed at, than perfectly explained.' Upon the same point also Dr Ure remarks: (Dictionary of Manufacture) 'but philosophers have been, and still are, too much estranged from the study of the useful arts, and content themselves too much with the minutiae of the

laboratory and theoretic abstractions.' Such being the state of our present knowledge of this subject, it may be doubted if a careful examination of the principles of the long established, cheap, and simple mode of manufacture of the native of India, might not lead to improvements and modifications, which would be found to answer better, than the operose methods of the English manufacture, which require much capital, costly building, and a considerable trade to make them profitable.

5. In England the fuel now most generally used in smelting the impure iron ores of the coal fields is coke; and the ore after being first roasted to separate the volatile impurities, as much as possible, is exposed to its action in blast furnaces, generally about forty-five feet in height, but varying sometimes from thirty-six feet to even sixty feet. In the middle, these furnaces are about twelve feet in diameter, but at top are contracted to about four feet, and at bottom, where the blast of air is introduced by pipes from powerful blowing machines, the diameter is only about two feet. The pressure upon the air forced into the furnace is about three pounds upon the square inch, and the quantity of air amounts generally to as much as 4,000 cubic feet per minute. The cast iron as it forms, falls down into the bottom of the furnace; which is always hot enough to maintain it in a state of fusion; where it is protected from the action of the blast by a covering of fused slag which floats upon it. These furnaces are kept in action unremittingly, night and day, for several years together; the metal being allowed to flow out every twelve hours in quantities of about six tons at a time. The material used in building the blast furnace is principally fire brick, and a pair of furnaces cost upwards of £1,800 sterling. The proportion of coal used in making a ton of cast iron, varies very much, from three tons in Wales, to sometimes eight tons in Derbyshire; but the use of heated air in blowing the furnaces has very much increased the quantity of the products of the blast furnace, and has also diminished the expenditure of fuel, but the quality of the cast iron is said to be deteriorated. The estimated expense of making a ton of cast iron is about £3 sterling.

6. For converting cast iron into bar iron, the first process generally employed in England is called 'refining', and consists in fusing about a ton of cast iron at once in flat open furnaces about three feet square, where it is exposed for two hours or more to the action of a strong blast, by which it is supposed a portion of the carbon it contains is burnt off. Much gas escapes from the surface of the metal during the operation, and a large

quantity of black bubbly slag separates, after which the metal when run out and allowed to cool, has a white silvery appearance, is full of bubbles, is very brittle, and has acquired the property of hardening by being suddenly cooled. In 'refining', about four or five hundredweight of coals is used to the ton of cast iron, and the metal loses from twelve to seventeen per cent of its weight.

7. The 'refined' cast iron, now termed 'fine metal', is then exposed in a reverberatory furnace, called the 'puddling furnace', to the action of the flame of a large coal fire, by which it is first partially melted, then falls into a coarse powder; and on being stirred up and presented to the flame, becomes at last adhesive and tenacious. It is then formed into large balls, and after receiving a few blows from a large hammer to consolidate it, is passed between rollers which squeeze out much of the impurities, and form it into 'mill bar iron'. This is however too impure for use, and it is necessary to cut the rough bars into pieces and to weld them together afresh, in a 'reheating furnace', and expose them to another rolling, and even to repeat the operation a third time, before good tough bar iron is produced. In the 'puddling furnace' about a ton of coals is expended to each ton of 'fine metal', and in the 'reheating furnace', about 150 pounds more are expended; and in each operation a loss of about ten per cent takes place in the weight of metal operated upon.

8. Upon an average about nine tons of coal are expended in England in forming one ton of finished bar iron, and it is probable, that if the above processes were attempted upon any smaller scale than that of the English works, a still greater quantity would be used. Some of these works cost £27,000, and turn out 120 tons of bar iron per week.

9. In France, Sweden, Norway, and parts of Germany, the fuel principally used is charcoal, and the ores are pure oxides of iron; the furnaces are about thirty feet in height, and in shape resemble in great measure the blast furnaces of England. Leathern forge bellows are frequently used to blow them, and the results vary from five hundredweight of cast iron per day, to sometimes five tons. The quantity of charcoal used also varies very much, from one and quarter ton, to two and half tons for each ton of cast iron, according to the nature of the mineral oxide smelted.

10. The cast iron thus made is treated with charcoal in a refining furnace, not differing much from the English ones, but the metal is not allowed to run out, the operation being

continued for nearly five hours, until the metal has become tenacious and adhesive, when it is removed in lumps of about two hundred weight each, which are forged under a large tilt hammer, then cut into smaller pieces, and is drawn out into bars at once. In this process the metal loses about twenty-six per cent of its weight, and 149 pounds of charcoal are consumed for every 100 pounds of iron produced.

11. Formerly a kind of furnace called in Germany a 'steuck often' was sometimes used, which was from ten to fifteen feet high, and three feet in diameter, resembling very much an iron founder's cupola furnace, but with a larger door, which was broken open after the operation was finished, which required about twelve hours, and the lump of cast iron weighing about a ton, was removed with powerful tongs to the refining furnace. The quantity of charcoal used was from two and a quarter to three and a half cwt. for every cwt. of cast iron, and about one and half cwt. more was required in the refining and forging, making the whole expenditure from four to five cwt. for every cwt. of bar iron.

12. In some parts of France, malleable iron is made at once from the mineral oxides of iron, in what are termed 'catalan forges', which are cavities about 16 inches square, and two feet in depth, sunk in the floor of the workshop, the blast being thrown in by a pipe sloping towards the bottom of the furnace. The cavity being filled with charcoal, the ore is added in small quantities, alternately with fresh charges of charcoal, and in about five or six hours a lump of iron is procured, weighing from two to four cwt. which is removed, and forged at once into bars. The expenditure of charcoal is very great, amounting sometimes to eight times the weight of the iron procured. But when wood is cheap and abundant, there can be little doubt this process would be a convenient one for smelting any of the mineral peroxides of iron.

13. The mode of smelting iron used by the natives of India, appear to be very much the same from the Himalayas down to Cape Comorin, and in some degree resembles that alluded to in paragraph 11.

The ore principally used is either the common magnetic iron sand found in the nullahs, or else pounded magnetic iron ore, separated from the ferruginous granite, but I have seen specular iron ore used by the Konds of Goomsoor.

14. The material used for the native furnaces, is the common red potter's clay of India, which unless carefully selected, is not generally very refractory, and will hardly stand a heat sufficient to fuse cast iron, but by mixing it with sand, and by concentrating the heat in the centre of the furnace as much as possible by a projecting blast pipe, the reduction of the ore is effected before the furnace has become much more than red hot; the operation being completed in about a couple of hours.

15. In constructing these furnaces, a platform about two feet square and five inches thick is first made, with a hole in the centre nine inches in diameter. A half-cylinder or curved piece is then formed also of the red clay, eighteen inches high, four inches thick, and thirteen inches diameter inside, and the same depth, and also a cone about two inches thick of the same height, and the same diameter at bottom, and seven inches at top. When these are quite dry, a little wet clay being put round the hole in the platform, the half-cylinder is placed upon it, and the open front is built up with clods of clay, and the inside part is plastered for two inches thick until a hollow cylinder is produced, about twenty-three inches deep, nine inches in diameter inside, and about six inches thick. When nearly dry, an arch is cut out in front at bottom about nineteen inches high, to form the door of the furnace. The cone is then placed on the top, and the inside plastered with clay to correspond with the bottom part, and the neck or throat reduced in the same way to about five inches diameter. The upper part of a chatty with the neck is then placed inverted on the apex of the cone, to form a funnel to conduct the charge into the throat, and the chatty and the whole of the outside of the furnace is then plastered over with clay about two inches thick, so as to give the appearance of a large sugar loaf enlarged a little at the point. When finished, the height inside from the bottom to the neck is about three feet ten inches, and the whole takes about a week to finish before it is quite dry.

16. The blast pipe is a cylinder of dried clay fourteen inches long, and about four inches thick, pierced with a hole of an inch in diameter. It is introduced into the furnace at the bottom of the door, with the point about the centre of the furnace, and about five inches above the bottom. The door is then closed with a tile of dried clay, and the outside is built up and secured with wet clay plastered over, a layer of charcoal dust, about two inches thick, having been first placed at the bottom of the furnace to prevent the reduced oxide adhering to it.

17. The bellows are two goat skins taken off the animal, by opening the hinder part only. The orifices at the legs are sewn up, and a piece of bamboo is inserted, and tied tightly into the neck of each skin, and these bamboos being inserted into the outer part of the blast pipe, which is made conical for that purpose, the vacant openings are then stopped with wet clay. The open end of the skin is finished by folding the edge of one side, as a flap, about four inches over the other edge, and sewing up the upper and lower corners, so as to leave a part of both flaps open for about nine inches. When the skin is filled with wind, and pressed, the inner flap closes therefore against the outer, and stops the passage. Each skin is managed by one man, who places it in his lap, and squeezes it down with the elbow and lower part of the right arm, grasping at the same time a projecting sort of handle of leather, formed at about the part where the tail of the animal might have been. To enable the blower to fill the skin again with wind, a piece of string is attached to the lower corner of the posterior part, which is tied to a peg driven into the ground about a foot behind the man's elbow, and keeps the skin distended to its full extent as it lays in his lap; and a loop of leather is also fastened to the outer flap, through which the arm is passed, by which the opening into the skin is distended upon raising the elbow; and the skin being pulled out horizontally by the neck in one direction, and the string and the peg in the other; upon pulling up the middle part vertically by the leather grasped in the hand, the skin is opened out into a triangular shape, and fills with wind through the open flap. While squeezing one skin in blowing also, by pressing the hand forward, so as to pull against the string attached to the posterior part, the valve flaps are made to close fairly and properly, so as to allow hardly any wind to escape. The left hand is employed in assisting the right, or in squeezing the distended parts of the skin upon the side. It will be observed, that as both the necks of the skins open into the blast pipe, a portion of the wind expelled from one skin passes back again into the other; as they are worked alternately, a defect which might have been remedied in a most simple manner, by attaching little hanging door valves to the ends of the pipes.

18. A small quantity of charcoal being thrown into the furnace, the fire is introduced, and the blast commenced, and the furnace is filled to the neck with about twenty-six pounds of charcoal. In about half an hour flame issues from the throat, and the fuel begins to sink, at which time the charge is commenced, which consists of ten pounds of charcoal and five pounds of ore,

wetted to prevent it running down too fast. The charge is repeated seven times, and the furnace is allowed to burn down, and in about two and a half hours as soon as welding heat sparks are seen to issue with the flame, the bellows are removed; the door broken open; and the lump of reduced iron is removed, and cut open while hot with a hatchet, to show the quality. Four men are required to work one of these furnaces, one being a maistry superintendent, and the other three labourers, and they are able to make about three lumps in a day of twelve hours, but after four days' work, the lining of the furnace is destroyed, and requires renewal.

19. The lumps which result from the native furnaces weigh about eleven pounds, and are sold sometimes at the rate of two annas each. They are not, however, all iron, and on bringing them to a welding heat in a forge, a large portion consisting of fused oxide, melts away, and the best lumps which I have examined yield only about six pounds of iron, (generally they do not contain more than three pounds). Taking forty rupees a ton as the expense of forging the iron into rought bars by hand hammers, we shall have eighty rupees a ton as the expense of bar iron, made with these diminutive furnaces, which is less than the present market price at Madras of the cheapest English bar iron. In my experimental investigation of the best methods of managing small blast furnaces, not larger than the native ones, I have found that two men can procure in a day's work of twelve hours forty pounds of crude iron, with an expenditure of half the quantity of charcoal and ore used by the natives. Furnaces of this size offer therefore a cheap, convenient, and ready mode of smelting iron wherever charcoal is abundant.

20. Although the aggregate manufacture of iron in India is no doubt very considerable, yet from the difficulty of inland transport in Southern India, it is probable that no extensive iron works will ever be established by European capitalists; and the only improvements which are capable of being introduced with advantage, or may be within the comprehension of natives, are those by which the expenditure of fuel may be economised by increasing the size of the furnace, and by which a sufficiently powerful blast may be produced. From my own experiments, I am led to believe, that the catalan forge will not answer except when the ores of the peroxide are procurable, in consequence of a peculiar property possessed by the magnetic oxide. But I am of opinion that the German, 'steuck often' might be used with great advantage, and the complete reduction of the ore at one

operation to malleable iron, is easily effected. One of these furnaces may be easily built for ten rupees. The bellows for it may cost about ten rupees. A small tilt hammer about fifty rupees, and the whole stock in trade capable of turning out a ton of bar iron per week, need hardly cost one hundred rupees. I believe that nearly all the jungly tracts of Southern India are granitic, and in them of course fire clay and magnetic iron sand abound. Charcoal can be made at about fifty pounds for an anna, and the iron sand is sold at thirty pounds for an anna, which prices are as cheap as the iron stone and coal are now sold for in South Wales.

21. With regard to the quality of the iron produced by the native methods, we have the most contradictory remarks from various authors; and indeed I am not aware of any good researches upon this point having been published. From what I have seen of Indian iron, I consider the worst I have ever seen to be as good as the best English iron, and that its supposed defects arise from its almost always containing a considerable portion of steel.

22. If it is attempted to bend a bar of English iron of inferior quality when cold, it will be found to snap short off, almost without bending at all, and the fractured end will exhibit a series of minute glistening planes inclined at irregular angles, and which by the lens, will be seen to resemble exactly the spangles of ‘kisk’, or graphite, which appear upon the surface of highly carburetted cast iron. A bar of the best English bar iron, when bent cold, will exhibit on the sides of the bent angle a series of longitudinal fissures, evidently produced by impurities between the fibrous portions, and before it is bent as far as an angle of 120°, it will break, and the fracture will be half glistening, and the rest very much resembling lead when forcibly pulled asunder. This last portion is the pure iron, and when viewed endways, will generally appear nearly black. The glistening portions are portions of carburet imperfectly reduced. It is a common remark of authors, that pure iron is either granular or fibrous in texture, the former being produced by sudden cooling, and the latter by elongation under the hammer. This remark I consider, however, to be erroneous, and I have never found pure fibrous iron to become granular, if properly worked, although granular iron will become fibrous; not, however, by the mechanical effect of the hammering, but by the action of the fire and blast reducting the carburet. In working the best kinds of English iron, they let fall upon the anvil a quantity of red powder, which very much resembles

in appearance the residue left by burning the carbon separated by muriatic acid from cast iron. Even the charcoal-made English iron will hardly bear drawing out under the hammer without splitting, and a small rod will generally snap after bending it two or three times. English hoop iron, although it will stand curling up into a roll of about ¼ inch in diameter, yet on the slightest attempt to bend it longitudinally into a hollow trough, it will crack in three or four places immediately. The following remarks by Dr Ure (Dictionary of Manufacture) are evidently from a person practically acquainted with the subject. 'The quality of iron is tried in various ways; 1. As first by raising a bar by one end, with the hands over one's head, bringing it forcibly down to strike across a narrow anvil at its centre of percussion on one-third from the other extremity of the bar, after which it may be bent backwards and forwards at the place of percussion several times. 2. A heavy bar may be laid obliquely over props near its end, and struck strongly with a hammer with a narrow pane, so as to curve it in opposite directions, or while heated to redness, they may be kneed backwards and forwards at the same spot on the edge of the anvil. This is a severe trial which the hoop (Swedish iron) bears surprisingly, emitting as it is hammered, a phosphoric odour peculiar to it, and to the bar iron of Ulverstone, which also resembles it in furnishing a good steel. The forging of a horseshoe is reckoned a good criterion of the quality of iron.'

23. There is hardly one of the above tests, which good native iron of Southern India will not bear, and some iron which was produced in my own furnaces, has stood drawing out under the hammer into a fine nail rod not th inch thick, without splitting, and when kneed backwards and forwards, only broke after six or seven times. When twisted like a hank of whipcord until some of the plies began to draw out, no fracture occurred in any part, and a half inch bar ¼ inch in thickness bore doubling together *cold*, and the angle hammered down close with very little signs of separation between the fibres. As I have shown that native Indian iron contains steel, the quality can be easily tested by a very simple method, which is merely to bring the middle part of the bar to a red heat, and then immersing it in water, by which all the steely portions will be rendered brittle, without the fibrous portions being affected. An inch bar of good iron thus treated will bear a dozen blows of a heavy sledge hammer before it will break.

24. The fractured end of a bar of Indian iron presents a very different appearance to that of English, none of the glistering portions being visible, but if not fibrous, it shows the granular fracture of an aggregation of crystalline grains, either large or small, according to the hardness of steel which it contains. The iron thus examined may be separated for different purposes into four different kinds.

1st. Completely fibrous. Fit for nails, horseshoes, bolts, straps, crowbars, tongs, & c., in which softness is of no consequence, and great tenacity and ductility are requisite.

2nd. Half fibrous and half granular. Fit for axle trees, wheel tyres, & c., where tenacity and strength are both requisite.

3rd. Nearly all granular and steely, resisting the file in some parts, and brittle, breaking with one or two blows of the sledge. Fit for lathe bars and iron work in mathematical instruments, where hardness is requisite to prevent bruising.

4th. All granular, with the fine snow-white fracture of cast steel in parts. Only touched by the file in some parts. Very brittle unless annealed. Hard, and resists the hammer in forging, drawing out with difficulty, and cracking slightly at the edges unless carefully forged. Fit for plough shares, spades, and pickaxes, bricklayers' trowels, & c. which require to be hard.

25. Some native made iron which I have met with was difficult to forge, from its cracking very much under the hammer at the edges of the bar, though not otherwise deficient in tenacity; but as such iron is not common, I have not had opportunities of examining it properly. The native workmen say, that iron of this kind is quite as ductile as any other if it is forged with bamboo charcoal. Should this be a fact, it seems to be well worth the attention of chemists, considering that the coat of the bamboo contains much finely divided silica, and remembering that the English smiths, when welding together steel and iron, use freely large quantities of a white quartzose sand. It is probable that it is this last kind of Indian iron, which has by some been called 'red short', which is however a mistake. The English red short iron snapping off like a carrot when bent.

XVII

ASPECTS OF TECHNOLOGY IN WESTERN INDIA

(Dr Helenus Scott, M.D., to Sir Joseph Banks, President Royal Society, London (circa 1790-1801).)

Bombay, January 7, 1790.

I had the pleasure of receiving a letter from you by the *Ponsborne* dated December, 1788.

I have according to your wish endeavoured to inform myself respecting the methods used by the natives of the country for cleaning cotton. Captain Dundas will bring you the only instrument they have for the purpose.

I have for several years past been attentive to the methods used by the natives of this country for dyeing their cotton cloths and I think I have discovered the singular circumstance by which they are enabled to give that permanency to the colour which is so much admired. I am unable to give any theory of the operation of the chief substance they use and without which they can do nothing. It seems in all cases when a cloth is wetted with an infusion of it and a solution of alum, and then put into a vegetable colour to deposit something which has a strong attraction at the same time for the cloth and the colouring principle and which renders them ever afterwards inseparable. It seems to have the same effect on animal dyes, if I be not mistaken on some trials that I have had made with cochineal. The natives have many methods of altering the colour of vegetables or heightening their splendour simply by the addition of acids or of alum or of water in which...(Indecipherable in original.—*Editor.*) of iron had been infused or the recent excrement of some animal while it still retains much of the volatile alkali & c. But I know that to render these colours durable on the cloth (after separating a number of circumstances that only in appearance conduce to that end) they have no other method than the one I have mentioned. If this appears to you a matter of consequence as the cotton manufacturers are now in so flourishing a condition in England I shall at some future period communicate more particularly their method to you.

It is extremely difficult to learn the arts of the Indians for the same caste, from father to son exercises the same trade and the punishment of being excluded from the caste on doing anything injurious to its interests is so dreadful that it is often impossible to find an inducement to make them communicate any thing. They in general care nothing for money if they have enough to buy their food and a little is sufficient for that purpose. As their knowledge of the arts is never communicated by writing nor printing nor their experience reduced to general laws by theory the difficulty of information is again increased.

The theory you have sent me of a gentleman whose name you do not mention regarding the caves and statues of this country appears to me very ingenious...

About 13 years ago on digging on the Esplanade of the Fort of Tannah in Salsette the workmen came to a stone box which contained plates of copper joined three and three by faring the same metal...

These plates are made of good malleable copper and worked with considerable art...From all this we may conclude that at so distant a period of 700 years copper was not a scarce article among the Indians as in this instance they use it so plentifully, and that it was not a new one for it is here a pure metal and worked with skill.

The people of this country from the pliable and human disposition of their minds increased by their climate and especially by their singular religion have always been able to assuage the fury of their conquerors and while they have remained a distinct body from those by whom they have been subdued, they have retained through all the revolutions of their government and perhaps from ages very remote a considerable degree of civilisation. I often think that their arts improved by the practice of so many years might afford matter of entertainment and instruction to the most enlightened philosopher of Europe. But seldom I believe have they been viewed by those whose knowledge and temper of mind and circumstances have enabled to make such enquiries with advantage. If I find it agreeable to you I shall now and then give you my observations on some of those objects of science.

I do not flatter myself that I am well qualified for such an undertaking which requires an intimate knowledge of natural philosophy and chemistry and the arts depending on them. But I hope to meet with your indulgence. I might also plead in excuse of my errors that my time is entirely occupied with the fatiguing duties of my profession.

I have sent you in the box that contains the machines for cleaning cotton a piece of the cinnabar of this country which is made in masses sometime of 100 lb weight at a single sublimation. I have very frequently tried to make cinnabar by the methods recommended in Europe but I have never been able to procure any so far, as the Indian at one operation. I should be glad to be informed if you wish to know the Indian method of making it...I find, too, that they make corrosive sublimate in this country but I never have been able to see the process.

I shall at an after-period give you an account of the methods of preparing the lime or as it is called chunam of this country for buildings, terraces, aqueducts, works below the surface of water and for the bottoms of ships where it answers the purposes of copper.

For works below the surface of water I think the Indians have an excellent method of preparing their chunam. In a few hours it acquires great solidity and especially the part of it that binds together the large stones which face the walls; for most trouble is taken with the chunam for that purpose. One of the chief ingredients is a kind of unrefined sugar which appears by Mr Bergman's experiments to contain more of the disengaged saccharine acid than refined. With this and some other substances the chunam is carefully mixed for a length of time and is occasionally wetted with a solution of the sugar in water. Does the great hardness that the lime so soon acquires below the surface of water depend on its attraction for the saccharine acid?...As far as I can learn no one has yet practiced a method similar to that used in this country...

Bombay, January 19, 1792.

I had the favour of your letter of the 17th March 1791 by the *Essex*, the last ship that arrived here from Europe. I was greatly flattered to find that what I had done was acceptable to you and that you give me encouragement to move into the subject which I proposed to you. The arts of India certainly afford the most interesting objects of enquiry. I have been always of that opinion and in the course of my stay in this country I have made many observations that in my opinion are worthy of being known. I hope by the *Essex*, which will sail in about six weeks hence, I may be able to begin the subject. Indeed, it is a field in which there are so many beautiful objects that one is distracted with the variety and at a loss to determine which is most worthy of his attention.

I think at present that I shall conduct myself in this enquiry in the following order, or in one somewhat similar.

First Their knowledge of medicine and surgery:

In medicine I shall not be able to praise their science very much. It is one of those arts which is too delicate in its nature to bear war and oppression and the revolutions of governments. The effects of surgical operation are more obvious, more easily acquired and lost by no means so readily. Here I should have much to praise. They practice with great success the operation of depressing the crystalline lens when it becomes opaque and from time immemorial they have cut for the stone at the same place which they now do in Europe. These are curious facts and I believe unknown before to us.

Secondly Their art of dyeing in which I have lately gotten much knowledge. Here I shall venture to recommend some substances as highly worthy of becoming articles in commerce and of being employed by our artists in Europe.

Thirdly Their method of using lime in buildings & c. in which also some new substances must be recommended.

Fourthly Their methods of making soap, gun powder, indigo, ink, cinnabar, vitriol and iron and copper, alum & c. & c.

I shall at the same time send you plentiful specimens of all the agents in their arts and think myself sufficiently repaid if you think I have contributed anything to the interests of science. Should anything that I transmit to you appear to be worthy of being printed I can have no objection to it. I need not beg of you to let nothing appear which you in the least disapprove of. I am very sensible of the honour you do me in offering the Philosophical Transactions for this purpose...

I have lately observed that the natives make immense quantities and at a very low rate a good fossile alkali by burning seaweeds. This appears to me also a valuable salt. I shall send you specimens of it. I think it would not cost here above 2-10 £ or 3 £ a ton.

Bombay, February 7, 1792.

I wrote you a few lines in much haste by the *Raymond* which sailed from hence about a month ago. I had not yet had leisure to do much in the subject I proposed to myself, but I hope to be able to send you my first attempt in a short time hence. I can not, however, defer any longer making you acquainted with the most useful substances that the Indians employ in their arts. You will afterwards see these uses more particularly mentioned when I describe their methods of preparing lime; of fixing colours, or of producing them.

This astringent substance is the drupa of a tree which grows very plentifully in the neighbourhood of this island, though I have not hitherto had the good fortune to see it in flower. From a long acquaintance with it I am well persuaded that it would make a cheap and good substitute for galls in dyeing and in other arts. In fixing some colours it has hidden powers which galls do not possess as I have experienced in the dyes of this country.

Your chemists will see at once the general nature of this substance and your artists will find how far, by such an agent, they can produce the effects to which they have been accustomed; but it is only future experience that can discover those properties by which it may differ from every other astringent substance.

This drupa with vitriolated iron, makes a very fine black and I have frequently made writing ink with it that was good in every respect. This letter will give you a specimen of it...I have been at the expense of sending 3 tons of it at once...

Bombay, January 8, 1794.

You will think the paper on putting on noses on those who have lost them an extraordinary one. I hope to send you by the later ships some of the Indian cement for uniting animal parts.

I enclose in one of the boxes a specimen of a kind of steel which is called wootz and is in high esteem among the Indians. It appears to admit of a harder temper than any thing we are acquainted with. I should be happy to have your opinion of its quality and composition. It is employed here for covering that part of gun-locks which the flint strikes, for cutting iron on a lathe, for chisels for cutting stones, for files and saws and for every purpose where excessive hardness is necessary. You must carefully observe that it can not bear any thing, beyond a very slight red heat, which makes its working very tedious to the blacksmiths. It has a still greater inconvenience. It can not be welded with iron or steel. It is only joined to them by screws and other contrivances. The blacksmiths who work in wootz generally consider it as a separate art and do not work in iron. When the heat is a little raised above a slight red heat part of the mass seems to run and the hole is lost; as if the substance consisted of metals of different degrees of fusibility...

Bombay, January 19, 1796.

I sent on some days ago by *Captain Villet* two boxes. One contains the god Gunnes, the other I find contains 183 lb of wootz (or butt) and 9 pieces of brass containing many figures from the Hindoo mythology. You may keep for your own trials one cwt. of the wootz and give the remainder to Dr Johnson.

In the little packet that contains this letter I send you a few of our newspapers where you will find some little essays that may afford you amusement. They certainly are not fit for the eyes of a critic. But we ought to meet with great indulgence separated as we are from the aids of science. You will also find the seeds that in my last letter I commend so highly as an agreeable and nutritious vegetable. In this packet too you will find a piece of *Caute*, the cement for noses. I hope soon to write you more fully on some subjects that appear interesting to me.

Bombay, August 15, 1801.

I received your interesting letter of the 23rd December last and as far as I am able at present I shall answer the different questions that you propose.

The natives of Malabar have made iron from time immemorial. I send you in a box about one or two cwt. of their iron after one fusion...I also send you a specimen of their ore. I can not pretend to say to what extent we might procure iron in Malabar for it has hitherto been made there only for their own purposes...I send you a sketch of a Malabar smelting furnace taken on the spot by my friend Major Walker now one of the commissioners for that province, which will give you an idea of their method. It combines together the air and blast furnace and is found to be very sufficient for their purposes...Manufacture of iron by the expenditure of fuel would do no injury there to other arts…Some of the Malabar blacksmiths work admirably in iron. I have seen for instance a pair of pistols made by them which were not inferior in beauty nor probably in any other respect to the best that are manufactured in London.

Copper as far as I know is not manufactured in India…

You are not unacquainted with the general use that is made of the cannabis in this country for intoxication. I am assured that its effects are less injurious and still more agreeable than opium. Those who get into a long habit of taking it can never again relinquish it. The common way of using it is to mix it with tobacco and to smoke them together. At times they bruise the leaves and drink their juice. Would it not be worth while to ascertain the effects of the cannabis as a remedy for disease, for opium with all its excellent qualities has also its disadvantages…

I have now I think mentioned all the heads of your letter but I beg leave to draw your attention for a moment to *dammer* a substance in universal use through the whole eastern world and of the greatest utility. It has often appeared to me very extraordinary that this unrivalled vegetable product should never have been brought into general use in Europe for on many occasions you have no sufficient substitute for it. We have kept our eyes in this country on diamonds and pepper and pearls while we have neglected the substances that would have improved our manufactures or created new arts among us. I take notice of *dammer* at present as you seem particularly desirous of getting substitutes in this country for the materials which are brought from the northern nations for our navy. *Dammer* dissolved in oil by heat is employed for covering the bottoms of ships, or in such as are coppered, for paving the seams of those parts that are above the copper. For those purposes it answers admirably well in this country as it does not soften by the heat of the sun. It is employed for covering wooden vessels for retaining water, or for channels that conduct it, for securing ammunition chests or powder barrels from wet and for many purposes of a similar kind. Although it is sometimes used as a varnish for terraces and other works made of lime, yet it does not last long for such purposes for the lime assisted by moisture decomposes it. It would be endless to specify the uses for which *dammer* is daily employed in this country. In order to apply it, it must as I have said be dissolved in oil by heat and applied while still liquid and hot. On cooling it becomes hard. I send you two specimens of *dammer*. The whitish kind is by far the most esteemed though the other sort is employed for many purposes. There can be no doubt but that you would find *dammer* in this way an excellent substitute for pitch and tar and for many purposes much superior to them.

Mr Philips in his rope work here has lately tarred our hemp and made it into rope that is supposed to be equal to any thing of the kind in Europe. He wants nothing but encouragement to do it on an extensive scale.

I may observe to you that I have lately learnt that there is a glutinous vegetable substance the produce of this country which has been employed (I fancy by the natives) as we employ tar, for securing the ropes from the effects of the weather. Mr Philips has seen ropes thus prepared. He says they are excellent.

Perhaps this may be a real improvement, for the tarring of hemp certainly weakens it while it preserves it from moisture. On this subject you need not doubt but that I shall make further enquiry...

The box contains the specimens of hemp and dammer.

Appendix I

Sources

Chapter

I. *Bramin's Observatory at Benares*, by Sir Robert Barker, was first published in the *Philosophical Transactions* of the Royal Society, London (Vol.67 for 1767, pp.598-607 and plates) under the title 'An account of the Bramin's Observatory at Benares'. The supplementary note by Colonel T.D. Pearse is taken from 'Memoir of Colonel Thomas Deane Pearse', referred to in No. IV below.

II. *Remarks on the Astronomy of the Brahmins*, by Prof. John Playfair, was first published under the same title in the *Transactions* of the Royal Society of Edinburgh (Vol.II for 1790, part I, pp.135-192).

III. *Hints Concerning the Observatory at Benares*, by Reuben Burrow, is on ff.263-76 in Add Ms.29233 amongst the Warren Hastings Papers in the British Museum. This paper is originally titled 'Hints concerning some of the Advantages derivable from an Examination of the Astronomical Observatory at Benares'. The last sheet of this paper is marked 'Mr Burrows' and a reference to it is made by R. Burrow in a letter addressed to W. Hastings on 12 June 1783.

IV. *On the Sixth Satellite of Saturn*, by Col. T.D. Pearse, is No.A.P.5/22 in the Archives of the Royal Society, London. It is in the form of a letter from Col. T.D. Pearse to the Secretary of the Society. A slightly varied version of it is included in the 'Memoir of Colonel Thomas Deane Pearse' originally published in the *British Indian Military Repository* for 1822-3. (This Memoir has been subsequently reprinted in *Bengal: Past and Present*, Vol.2-7).

V. *A Proof that the Hindoos had the Binomial Theorem*, by Reuben Burrow, was first published under the same title on pp.487-97 in Vol.II (1790) of the *Asiatic Researches*.

VI. *Hindu Algebra*, by H.T. Colebrooke, was first published in 1817 titled *Dissertation* in his 'Algebra with Arithmetic and

Mensuration, from the Sanscrit of Brahmegupta and Bhascara'.

VII. *Operation of Inoculation of the smallpox as performed in Bengall*, is an extract from a letter dated Calcutta, 10th February, 1731, from Ro. Coult to Dr Oliver Coult, giving 'An account of the Diseases of Bengall'. It is on ff.271v-272r in Add Ms.4432 amongst the Royal Society papers in the British Museum.

VIII. *An account of the Manner of Inoculating for the smallpox in the East Indies*, by J.Z. Holwell, F.R.S., was published by him in 1767 under the same title and 'inscribed to the learned the President, and Members of the College of Physicians in London'. (The sub-title to the publication reads, 'With some Observations on the Practice and Mode of Treating the Disease in those Parts'.)

IX. *The Method of Making the Best Mortar at Madrass in East India*, by Hon'ble Isaac Pyke, Governor of St Helena, was first published under the same title on pp.231-5 in Vol.37 (AD 1732) of the *Philosophical Transactions*.

X. *The Process of Making Ice in the East Indies*, by Sir Robert Barker, F.R.S., was first published under the same title on pp.252-7 in Vol.65 (AD 1775) of the *Philosophical Transactions*.

XI. *Uses of the Son and Manufacturing of the Hindostan Paper*, by Lt. Col. Ironside, was first published on pp.99-104 of Vol.64 (AD 1774) of the *Philosophical Transactions*. It was then titled 'Of the Culture and Uses of the Son or Sun—plant of Hindostan, with an Account of the Manner of Manufacturing the Hindostan Paper'.

XII. *Indian Agriculture*, by Col. Alexander Walker, from a much larger work (circa 1820) on the agriculture of Malabar and Guzarat, is taken from 184.a.3 (pp.577-654) amongst the Walker of Bowland Papers in the National Library of Scotland.

XIII. *On the Drill Husbandry of Southern India*, by Captain Thos Halcott, originally in the form of two letters, was published on pp.352-6 in the 1st volume of 'Communications to the Board of Agriculture' published in 1797. It was then titled 'On the Drill Husbandry of the East'.

XIV. *Iron Works at Ramanakapettah*, by Dr Benjamin Heyne, was originally sent by him in 1795 to the Governor of Madras. It is then titled as 'Doctor Heyne's Report of the Iron

Works at Ramanakapettah' and this version is taken from Vol.1 (No.613) of the Board's Collections in the India Office (IOR:F/4/I). An edited version of it was also published by Dr Heyne in 1814 as No.13 'Tracts, Historical and Statistical on India'.

XV. *The Mode of Manufacturing Iron in Central India*, by Major James Franklin, is in the India Office Library as MS EUR D 154, and is noted as 'Received from Secretary May 19, 1835'. The whole of this document along with the seven plates (but excluding the map) is published here. The original is titled 'Observations on Several Iron Mines, in the Central Part of India, with an account of the Indian Mode of Manufacturing Iron and Plans of the Machinery and Implements'.

XVI. *Manufacture of Bar Iron in Southern India*, by Captain J. Campbell, Assistant Surveyor General, Madras, was written around 1842 and was published in *The Calcutta Journal of Natural History* for 1843 (Vol.3, pp.386-400) under the same title.

XVII. *Aspects of Technology in Western India*, consists of extracts from letters addressed from Bombay by Dr H. Scott to Sir Joseph Banks, President of the Royal Society, London, during 1790-1801. The extracts reproduced here are from Add Ms.33979 (ff.1-13; 127-30; 135-6; 233-6); Add Ms.33980 (ff.305-310) and Add Ms.35262 (ff.14-5) in the British Museum.

Appendix II

Biographical Notes on Authors*

BARKER, Sir Robert (d. 1789), for some time commander in chief in Bengal, author of Chapters I and X, probably first came to India about 1749. He was promoted brigadier-general in 1770 and commander in chief thereafter. After a lively quarrel with Warren Hastings he left India and on reaching England was elected member of parliament. He seems never to have spoken in parliament, but in March 1781, was rewarded with a baronetcy for his consistent vote with the government.

BURROW, Reuben (1747-92), mathematician, author of Chapters III and V, was born 30th December 1747, near Leeds. He showed a taste for mathematics, and after various jobs, was appointed around 1770, assistant to Maskelyne, then astronomer-royal, at Greenwich. In 1782 he accepted an appointment in India, procured by his patron, Col. Henry Watson, for many years chief engineer in Bengal. In Bengal he was appointed mathematical teacher of the engineers' corps and was connected with the proposed Trignometrical Survey of Bengal. He was one of the first members of the Asiatic Society. He died at Buxor on 7th June 1792.

COLEBROOKE, Henry Thomas (1765-1837), author of Chapter VI, was the son of Sir George Colebrooke, the head of an old and wealthy firm of bankers, and chairman of the East India Company in 1769. He came to India in 1782, was appointed assistant collector in Tirhut in 1786; during 1799-1801 he was Resident to the court of Nagpur; and in 1807 attained a seat on the Governor General's Council from which he retired after a total service of thirty-two years. The (British) *Dictionary of National* Biography calls him the 'first great Sanscrit scholar of Europe'.

HEYNE, Dr Benjamin, author of Chapter XIV, was acting Company's botanist employed in the Madras administration. In 1814 he published his 'Tracts, Historical and Statistical on India'.

HOLWELL, John Zephaniah (1711-1798), Governor of Bengal, author of Chapter VIII, was born in Dublin on 17th September 1711. He came to Calcutta, as Surgeon's mate to an Indiaman in February 1732 and practised his profession in Calcutta from 1736 onwards. He was temporarily Governor of Bengal from February to July 1760. His contribution to Eastern knowledge called forth the warm acknowledgement of Voltaire. Holwell died on 5th November 1798.

PEARSE, Thomas Deane (d. 1789), colonel, author of Chapter IV and supplementary note to Chapter I, born about 1738, was appointed second lieutenant Royal Artillery on 24th October 1761 and was transferred to the East India Company's service in February 1768. In India he was high in the favour of Warren Hastings, and acted as Hasting's second in his duel with Sir Philip Francis on 17th August 1779. Pearse died on the Ganges on 15th June 1789.

PLAYFAIR, John (1748-1819), mathematician and geologist, author of Chapter II, was born near Dundee (Scotland), on 10th March 1748. He graduated in 1765. He then completed his theological course, and was licenced by the presbytery as a minister in 1770. He was elected moderator of Synod, at Liff in 1774. In 1785 he became joint professor of mathematics in the university of Edinburgh, and in 1805 exchanged his mathematical chair for the professorship of natural philosophy in the same university. Playfair was one of the original members of the Royal Society of Edinburgh, of which he subsequently became general secretary and held this post till his death. He was elected a Fellow of the Royal Society in 1807.

SCOTT, Helenus (1760-1821), writer of the letters given in Chapter XVII, entered the medical service of the East India Company, and served chiefly in the Bombay presidency. After thirty years in India he returned to England, and began practice at Bath. In 1815 he was admitted a licentiate of the college of physicians, in London, and in 1817 began to practice as a physician in Russell Square, London. In the same year he contributed an interesting paper to the 'Transactions' of the Medico-Chirugical Society on the use of nitromuriatic acid in medicine. He used it on a wider range of disease than is now customary; but its frequent employment in the treatment of enteric fever and other maladies at the present day (circa 1900) originates in his advocacy of its merits. He attained to considerable practice, and died on 16th November 1821.

WALKER, Alexander (1764-1831), brigadier-general, author of Chapter XII, was born on 12th May 1764. He was appointed a cadet in the service of the East India Company in 1780. He took part in the last war against Tippoo, and was present at the battle of Seedaseer in 1799 and at the siege of Seringapatam. In June 1802, Walker was appointed as Political Resident at Baroda. He returned to England in 1810 and in 1822 was called to the Government of St Helena. He died at Edinburgh on 5th March 1831, soon after retiring from the governorship of St Helena. While in India Walker formed a valuable collection of Arabic, Persian, and Sanscrit manuscripts, which was presented by his son, Sir William in 1845 to the Bodleian, Oxford, where it forms a distinct collection. His voluminous papers in English are in the National Library of Scotland, Edinburgh.

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DHARAMPAL: LIFE AND WORK

Born in 1922, Dharampal had his first glimpse of Mahatma Gandhi around the age of eight, when his father took him along to the 1929 Lahore Congress. A year later, Sardar Bhagat Singh and his colleagues were condemned to death and executed by the British. Dharampal still recalls many of his friends taking to the streets of Lahore, near where he lived, and shouting slogans in protest.

Around the same period, there were excited discussions, especially in school, about whether the British should leave India. Some were against *swaraj* because they feared invasion of the country by Afghan tribesmen and others. With many others his age, Dharampal tended more and more towards the *swaraj* option. Though he underwent western education throughout school and college, his animosity to British rule grew year by year. By 1940, he had started to wear *khadi* regularly—a practice he follows even now—and even tried to take to spinning the *charkha* for a while.

In 1942, he was present as a fervent spectator at the Quit India Session of the Congress in Bombay and he thereafter joined the Quit India Movement. He was active in it till he was arrested in April 1943. After two months in police detention, he was released but externed from Delhi.

Dharampal recalls he was one of countless people who believed that once the British were gone, India would be rid of its misfortunes, particularly its state of disorganisation and impoverishment.

In August, 1944, he was introduced to Mirabehn by his friends. He joined her soon thereafter, at what came to be known as the Kisan Ashram, situated midway between Roorkee and Haridwar. He stayed with Mirabehn, with occasional absences in Delhi (1947-48) and England (1948, 1949) till about 1953 when she retired, first to the Himalayas, and a few years later, to Europe. But the contact stayed. Dharampal met her again for the last time in July 1982 in Vienna, about two weeks before her death. On that day, they talked together for some 6-8 hours in the quiet of the Vienna woods.

Earlier, during 1947-48, Dharampal had come in close contact with Kamaladevi Chattopadhyaya, Dr. Ram Manohar Lohia, and with numerous younger friends in Delhi. He was then associated with an attempt at cooperative rehabilitation of refugees from Pakistan. (He was a member of the Indian Cooperative Union which was founded in 1948 with Kamaladevi as its president.)

The following year, while in England, Dharampal got married to Phyllis who was English. Afterwards, they both decided to live in India. On their way back, they spent some time in Israel and visited a few other countries as well. In 1950, the community village of Bapugram in the Pashulok area, near Rishikesh, began to be formed. Dharampal and Phyllis lived in it till 1953. He returned to England with his family in 1954.

He was back in Delhi again from early 1958 to 1964 with his wife, son and daughter. He now took up the post of General Secretary of the Association of Voluntary Agencies for Rural Development (AVARD); Kamaladevi was its first president. Soon thereafter, Jayaprakash Narayan agreed to be the president of AVARD. (He remained president till about 1975.)

For about two years (1964, 1965) Dharampal worked with the All India Panchayat Parishad (A.I.P.P.) as Director of Research and spent more than a year in Tamilnadu collecting material that was later published as *The Madras Panchayat System*. Earlier, in 1962, he had already published a smaller book containing the proceedings of the Indian Constituent Assembly relating to the discussion on the subject of "The Panchayat as the Basis of India's Polity".

From Madras, for family reasons, Dharampal once again moved to London in early 1966. His son had met with a serious accident.

By then he was also keen on a detailed study of the Indo-British encounter during the 18th and 19th centuries. This time he stayed on in London till 1982, but visited India in between. In England, he did not have much of an income. There was also a family to support. But notwithstanding all this, he became a regular visitor to the India Office and the British Museum and spent most of his time poring over the archives. Photocopying required money. Oftentimes, old manuscripts could not be photocopied. So he copied them in long hand, page after page, millions of words, day after day. Thereafter, he would have the copied notes typed. He thus retrieved and accumulated thousands of pages of information from the archival record. When he returned to India, these notes—which filled several large trunks and suitcases—proved to be his most prized possessions.

From around 1958, Dharampal had developed an association with Sevagram, especially because of Annasaheb Sahasrabudhe. He spent around a month in Sevagram in 1967, where he did his first writing based on the 18th-19th century data he had collected. His next long stay in Sevagram was from December (1980) to March (1981) when he completed *The Beautiful Tree*. From around August 1982 to 1987, he was mostly in Sevagram with occasional sojourns in Madras.

Dharampal was president of the Patriotic and People-Oriented Science and Technology (PPST) group. He was also closely associated with the Centre for Policy Studies located in Madras.

His wife died in London in 1986.

From 1993, he has been living largely at Ashram Pratisthan in Sevagram.