VII. BIOLOGICAL SCIENCES

BIOLOGY IN ANCIENT AND MEDIEVAL INDIA

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In its earliest beginnings, every science seems to have sprung into existence largely because of utilitarian reasons and biology was no exception. The foundations of life sciences in India were, however, laid during the period represented by the Indus Valley Civilization. This is about the same time when the Assyrian, Babylonian and Egyptian Civilizations too had attained an almost similar standard of development though some of them excelled in the knowledge of human anatomy and physiology.

The Vedic Age was conducive to investigating the problems and mysteries of nature. To a small extent there existed the scientific study of plants and animals. Evidences from the post-Vedic literature indicate that systems of classification and nomenclature were well advanced. The art of improvement of plants and animals was being practised. The knowledge of manures, rotation of crops, photosynthesis and respiration existed in a modest way. Animal metabolism, circulation of blood, nervous and reproductive systems as well as embryogenesis were understood. Some diseases and pests of animals and plants, and their preventive and curative remedies were known. Speculations on evolution were also made.

With the decay of the Hindu and Buddhistic cultures, there was a gradual decline in biological knowledge. The spirit of search for truth dwindled further during the medieval period under the pressure of orthodox religion and due to disturbances caused by Muslim invasions so that biology almost ceased to advance in this country. A renewed interest in life sciences grew up when Portuguese, followed by Dutch, French and later British, landed on Indian soil.

History of biology in India is not a finished subject but presents a host of problems which can be gainfully explored. However, several difficulties confront an investigator engaged in such studies. These can be partly overcome by offering proper incentives, liberal funds and governmental patronage and partly by team-work between a biologist, a linguist and a historian.

INTRODUCTION

'The History of Indian Science is one of the longest of all and one of the most amply documented. It begins in about 2500 B.C., and India continues to make original scientific contributions to this day. Though science was at first mentioned only incidently, over the centuries it became the subject of an immense number of specialized works, many of which are unfortunately lost.'[1] As far as biology is concerned, there is an oft-repeated question whether this science of animals and plants existed in any form in ancient India. Many earlier scholars have endeavoured to answer this query, and opinions have been expressed for and against it. In his chapters on the History of Botany in India, Burkill[2] writes that the science of botany 'is exotic to India as a system of

knowledge' and it 'spread over the World, India included, through Europe'. Similar comments are often made by others too. However, the analysis of ancient Indian literature made by Majumdar,[3] Seal,[4] Hora,[5] Srinivasa Rao,[6] and Maheshwari and Kapil[7] reveals the fallacy of such statements. There are numerous evidences in the form of seals, tablets, copperplates, edicts, inscriptions, palm leaves, sacred scriptures, epics, mythological stories, tibetan writings, archives of monasteries, unpublished manuscripts and literary treatises from which it is possible to decipher the knowledge about plants and animals as it subsisted in ancient and medieval India. The whole mass of traditions cannot be ruled out simply as incredulous, superstitious or metaphysical though useful information has to be salvaged and properly evaluated. Besides, care has to be taken to trace the origin, growth, progress and development of biology through the ages so as to have a perspective view of the way in which this science has advanced in India. It is no exaggeration of achievements out of patriotic sentiments when we say that the Hindus, no less than Greeks, have contributed to the shaping of biological ideas.

While writing this account, I have leaned heavily on the studies, translations and interpretations of learned scholars who have analysed the ancient literature carefully and critically. However, scientific standards have not been sacrificed in spite of the fact that lot of information is from secondary sources. Biology has been interpreted strictly as the study of animals and plants. Agriculture, horticulture, medicine and animal husbandry have been referred to only when essential to develop the main theme.

The article presents a brief but unbiased, preliminary, and historical survey of the development of biology in India. Its growth has been traced right from the prehistoric times through the Vedic and Medieval Ages to almost the beginning of the eighteenth century. It would be apparent that the story has been developed mainly from the side of plant life; not that the zoological side has been ignored but my familiarity with the zoological works is insufficient to justify proper evaluation of the achievements made in this field. Although the main objective of this paper is to elucidate whether biological science existed in ancient and medieval India, and if so, in what form; an attempt has also been made to compare the state of our knowledge with contemporary civilizations. Another aim is to highlight the problems on which future investigations in the field of history of biology in India could be rewarding. Some important sources from which ancient biological ideas could be tapped have been listed. The difficulties confronting an investigator of history of biology have been discussed and some suggestions offered to popularize the study and research in this field.

In a work of this kind the authenticity of dates of various sources is very important since they are going to decide the question whether Greeks and later Arabs have been influenced by the Hindus or *vice versa*. This is not

only a delicate point but also full of speculations and controversies. This difficulty has been overcome by largely depending upon the 'working hypothesis' put forth by the Chronology Committee constituted for this purpose on the occasion of a symposium on 'History of Science in South Asia' in 1950 under the joint auspices of UNESCO and NISI and adopted by the general meeting of the Symposium on 7 November 1960.[8] The recent modifications, wherever available, have also been taken into account.[9]

Prehistoric Beginnings

One can only speculate on the activities of the earliest inhabitants of India whose existence is known to us from some records consisting of rude implements which they used in their daily life. They could not make pottery and probably did not even know how to make fire. They were not aware of the methods of agriculture but lived on animal flesh and such fruits and vegetables as grew wild. According to Piggott[10] the Lower Paleolithic man of India may have been well equipped with 'impermanent substances as wood, fibre, grass, leaves or other organic materials such as skin and leather.' The geological background of Indian history indicates that in the Pleistocene remains bones of the buffalo, horse, bear, an extinct species of rhinoceros, hippopotamus, elephant and crocodile are scattered in the clay, sand and gravel beds of Narmada and Tapti. The earliest prehistoric relic of man discovered in India is regarded as of the pre-Chellean Age.[11] 'With a varied and abundant animal population as their codenizens in the fertile and well-watered plains of North India it is no wonder that early man in India was among the first to tame some of the more prized varieties for companionship and domestic service.'[12] Wheeler,[13] however, opines that 'in fairness to our proto-Indians of the Old Stone Age, let it be said again that we know almost nothing about them.' 'It is suggested that the handaxe was "an excellent instrument for digging up roots, grubs and other food from the ground"; truffles with a handaxe.'

Writing about the Mesolithic Age men of India, Sankalia[14] states that 'they were primarily hunters and subsisted on such games as the cow, buffalo, wild horse, ox, sheep, goat, rats, fish and crocodile. They must have used jungle fruits and other forest products... The dog also must have played an important part in the life of these people, as so far two almost complete skeletons have been found near the human remains...'[15] It seems that bark and hide were being used by Stone Age people.

From the remains of the Neolithic Age, it is distinct that ancient Indians employed primitive methods of cultivation of land, grew fruits and corn, domesticated animals, sewed hide with bone needles, made pottery and produced fire by the friction of bamboos or pieces of wood. Positive proof is, however, needed to establish these facts by further excavations.[16] According

to Zeuner[17] '... there is evidence from the Near and Middle East and from India of sickles and grinding stones, illustrating the stage of gathering of wild grasses' by pre-Neolithic peoples.

Furon[18] believes 'that rice has been cultivated in China since 5000 B.C., date-palms have been fertilized artificially and propagated by cutting since about 4000 B.C.; and that 250 species of plants were cultivated by prehistoric man, including a number of graminaceous species. On the other hand, Piggott[19] maintains that 'rice cultivation began earlier in India than it did in China, and that the knowledge reached the latter country by way of Yangtze, to make its appearance in the Chinese Bronze Age about 2000 B.C., the Neolithic crop in North China having been millet. But by 2000 B.C. agriculture had been established for at least three thousand years in Persia and Mesopotamia, and for a thousand in Western India...' (*see also* Hawkes).[20]

There is no evidence so far if the ancient Indians knew anything of anatomy although from cave drawings elsewhere we know that prehistoric man had some ideas about it. For example, at Lespugne, a plate representing a fish shows the gills, mouth, two eyes, vertebral column and the fishbones. Another fish, at Gondain, carved from a sliver of bone, bears a diagrammatic sketch of the digestive tract.[21]

As years rolled by, the ancient Indians acquired greater knowledge of nature but it was through a simple way of trial and error and no scientific study of plants and animals existed worth the name.

The Protohistoric Period

Coming to the age of metals, one encounters a highly developed civilization, the remains of which have been discovered at Harappa, between Lahore and Multan of West Punjab; and at Mohenjo-daro ('Mound of the Dead') in the Larkana district of Sind. This is collectively known as the Indus Valley Civilization (the Harappa culture) and ranks well with those of the Valleys of Nile, Tigris and Euphrates and was contemporaneous with the Assyrian, Mesopotamian, Egyptian and Chinese cultures. Unfortunately, there are no written records, and whatever glimpse of India is available during this period, is entirely based on the examination and interpretation of the archaeological excavations. Among the many new sites of the Indus Civilization excavated recently in India, Lothal (Ahmedabad, Gujrat) and Kalibangan (Ganganagar, Rajasthan) have also yielded a great deal of information.

Specimens of wheat and barley unearthed among the ruins of Mohenjo-daro disclose that probably both these grains were cultivated. The club wheat is *Triticum compactum*, and the plumpest form approaches *T. sphaerococcum*. Some experts consider that it is the Indian dwarf wheat, *T. sphaerococcum*. The barley has been identified as *Hordeum vulgare*.[22] According to Percival (quoted in Reed),[23] the earliest grains of barley discovered so far are

from Mesopotamia and belong to a period 4000 B.C. or earlier. Both wheat and barley have also been spotted from the earliest graves of Egypt. *Hordeum vulgare* brought to light in pre-dynastic graves is the same as that found at Mohenjo-daro, and is considered to be a later species than the wild *H. spontaneum* which is a native of Western Asia (ref. 22, p. 587). Reed (p. 13) believes that these grains were cultivated in Egypt probably in a period extending from 5000 B.C. down to 3400 B.C., and the seeds of a naked wheat belong to *Triticum durum*. However, Peake (*see* ref. 22, p. 587), in his Presidential address to the Royal Anthropological Institute (*J.R. anthrop. Inst.*, 57, 1927) remarks: 'It is clear that wheat, and the practice of cultivating this grain, must have reached Egypt from Asia, where the plant is native'. The same is probably true of barley.

Among the fruits, dates were cultivated at Mohenjo-daro and there is no reason to think that these were imported from abroad (*see* ref. 22, p. 587). Melons, and some vegetables were also grown.[24] Harappa cultivated peas and sesamums[25] (Vats 1940, quoted in p. 174). As compared to these, the Assyrians grew apricots, figs, olives, pomegranates, quinces and grapes, and the date-palm fruits were utilized in various ways.[26]

The plant forms represented on the seals from Indus Civilization are rare. They have been found only on 12 seals. Some of these have been identified as *Ficus religiosa*, *Acacia arabica* (*bābūl*) and *Prosopis spicigera* (*jhaṇḍi*) trees.[27] Like the cult of the tree in most ancient religions of the world, worship of *pipal* (*Ficus religiosa*) and banyan (*Ficus benghalensis*) was probably common in this civilization as well. It seems that occasionally animal sacrifices (of goat) were offered.

One of the most interesting crops grown by the people of Mohenjo-daro and Harappa civilizations was cotton. Garments were of cotton and wool. It is clear that the plant, whose fibre was used extensively for wearing, belonged to *Gossypium arboreum* type and not to any wild cottons. According to Zeuner,[28] the Mohenjo-daro cotton was in no way primitive but had all the measurable characteristics of modern Indian cotton. Its evolution from wild plant must thus have occurred very early. It is certain that wool was also employed as the sheep was well known, being one of the many animals portrayed in clay. There is a strong probability that flax too was used for garments as was the case in early Sumer and Egypt. An ancient fabric found in association with coins of Hyderabad was identified by Ghosh[29] as of *Crotalaria juncea*. Some of the trade with Mesopotamia was in cotton goods. By later historic times in that country 'Indian cotton was known under the name of *sindhu*, and this in the form *sindon* passed into Greek'.[30, 31] Zeuner[32] also believes that 'cotton did not enter the Mediterranean world until the fifth century B.C., when it appeared in the Nile Valley. Somewhat before this it was known to the Assyrians as a kind of tree-wool. The Babylonian and

Greek names point to an Indian origin, and this is confirmed by finds in Mohenjo-daro (2500 – 1500 B.C.)'. It may be mentioned that flax was cultivated in Egypt from very early times but the discovery and utilization of papyrus is one of the greatest biological accomplishments[33] of the Egyptians. The credit for the domestication of the silkworm goes to China where the larva of a drab moth seems to have been employed since 2600 B.C. when the Empress of Huang-Ti domesticated it.[34]

The Indus Valley people understood the qualities of wood and the strength, durability and preservative power of various timbers did not escape their notice.[35] Harappan plant remains examined by Chowdhury and Ghosh[36] have revealed that *Dalbergia latifolia* (rosewood) and *Cedrus* (probably *C. deodara*) were utilized for making coffins. Remains of *Zizyphus* sp. (ber) and *Ulmus* sp. (elm) have also been identified. The former was used as a mortar for pounding grains. Use of this particular timber indicates that the Harappans were not only aware of its shock-absorbing quality but also knew about its good seasoning property.[37] That even the Lothal people had good knowledge about the preservation and other characteristics of various timbers can easily be imagined, especially when they were making dockyards and ships.

In addition to plants, animal food was eaten. This included mutton, pork, beef, poultry eggs, and flesh of gharial, turtle, tortoise, fresh-river and dried fish. Animals were domesticated and wild. Indus seal motifs frequently represent the 'Brahmani bull' and other animals. Apes, parrots and peacocks were familiar to the Indus artist. Seals, clay models of toys and painted pottery indicate that buffalo (*Bos bubalus*), rhinoceros (*R. unicornis*), tiger (*Felis tigris*), dog (*Canis familiaris*), bear (*Sus cristatus*), horse (*Equus capallus*), donkey, deer (*Cervus axis*), elephant (*Elephus maximus*), and small animals like the squirrel, mongoose (*Herpestes auropunctatus*), black rat (*Mus rattus*) were known to the inhabitants. Harappa knew of the domestic cat.[38, 39, 40] Though birds are difficult to recognize, dove is likely to be present.[41] Seymour Sewell and Guha[42] and Srinivasa Rao[43] have given detailed lists of animals caught for food, used for ornaments and medicines and those domesticated, along with their equivalent zoological names. Almost 39 species of animals—26 vertebrates and 13 invertebrates—have been enumerated in all.

Excavations of other protohistoric sites like Rangpur (Surendranagar, Gujrat) have brought to light as many as 1,847 fragments of bones. It appears that *Bos indicus* Linn. was the most favourite domesticated animal although other animals like *Ovis vignei*, *Capra hircus aegagrus*, *Sus scrofa* Wagner, and *Bos (bubalus) bubalis* Linn. were also domesticated.[44] Among the plant remains timber of *Acacia* was predominant and *Albizzia* was next in importance. Some samples have been identified as belonging to *Soymida febrifuga* Juss., *Pterocarpus santalinus*, *Tamarix* sp. and *Melia azedarach*

These must have been used in religious ceremonies and for making houses, agricultural implements, vessels, toys and boxes. Two types of cereals—*Oryza* sp. (rice) and *Pennisetum typhoides* (bajra)—have been recorded. According to Ghosh and Lal[45] no grains or spikelets of rice have been observed but the manner of utilization of its by-product, husk, indicates not only their prevalence in the region but the state of their knowledge of these plants. Distinct charred grains of *Pennisetum* have been dissected out from carbonized spikelets. Ghosh[46] has reported rice among the plant remains from Lothal also.

There is not enough evidence of the knowledge of sexuality in plants in the Harappa culture. Historically, the biological discovery of sexuality seems to have been made by Assyrians in date-palm. Sculptures show that they artificially pollinated the spathes of the pistillate trees.[47]

Although the Indus Valley sculptures give an astonishingly accurate idea about the external features of human males and females as well as other animals, there is little information from the anatomical viewpoint. On the other hand, the Babylonians had a considerable knowledge. Preserved clay models of viscera of the body prove that the corpses were dissected. The Egyptians too perfected the practice of preserving dead bodies from putrefaction by conserving skeleton, and later by embalming.[48] They thought that the blood vessels carried air, water and excretory fluids. They described with general accuracy the larger bones and viscera, and recognized the function of the heart as the driving power of the organism and the centre of the circulatory system.[49]

It can be speculated from the above account that the Indus Valley people understood the life history of plants and animals in a general way. They were familiar with their successful raising and propagation. They must have had an inkling about the animal and probably plant breeding methods but knew little about their anatomy and physiology. Thus, it was during this period that the seeds of biological studies were sown in a casual way.

Biology in Vedic Literature

Like all ancient people, the men of the Vedic Age lived in close association with nature. They obtained their food, manufactured their implements and found remedies for illnesses from plants and animals around them. To these they gave some names, observed their activities, and studied their properties. If this knowledge can be called biology, the history of this science can be carried back into this dim past.

In compositions like the Vedic *Saṃhitās*, their *Brāhmaṇas*, the *Upaniṣads* and the *Sūtras*, one not only finds a large number of terms used to describe the external and internal parts of plants and animals but also a definite attempt at their classification. The Vedic literature is rich in many ideas which can be

classified under the present-day disciplines like the nomenclature, classification, morphology, anatomy, embryology, physiology, ecology, plant and animal diseases, economic biology, heredity and evolution.

The Vedic sages gathered information about the form, taste and properties of plants. They described and classified them. A perusal of the *Vedic Index of Names and Subjects*[50] and *Vanaspati*[51] brings to light a large number of plants and animals (*see also* Aiyer),[52] for which equivalent scientific names have been found out by experts. About 739 plants[3] and over 250 animals are referred to in the ancient literature. The entire 24th chapter of *Yajurveda* contains rich material regarding zoology.[53] A great variety of birds, and nearly 21 kinds of snakes are enumerated, each by its own special features of colouration, structure or habit. The term 'worm' has been vaguely used. Microscopic bacteria and insects of terrestrial and aquatic origin also find a mention.[54] References to fish and fishermen are not lacking.[5] It appears that the plants and animals were christened according to certain principles. Names were either associated with their utility, habitat or special features.

Broadly, the vegetable world was divided into trees, herbs, shrubs, creepers and grasses (*Ṛgveda*, x, 97, 15; i, 164, 20, 22; i, 161, 1; *Atharvaveda*, viii, 7). *Vṛkṣa* is the term for trees in *Ṛgveda* (ii, 14, 2; 39, 1, etc.) and *Oṣadhi* or *Vīrudh* denotes minor vegetable growth like herbs (*Atharvaveda*, i, 32, 3; 34, 1; ii, 7, 1; *Ṛgveda*, ii, 1, 14; 7, 67, 9). The plants included under *Oṣadhi* possessed healing power (*Ṛgveda*, x, 97) whereas those included under *Vīrudh* did not possess medicinal properties (*Taittirīya, Saṃhitā* ii, 5, 3, 2). *Tṛṇas* meant grasses (*Ṛgveda*, i, 161, 1).

Paśu indicated animals including man. *Jagat* denotes domestic animals as against *śvāpad* meaning wild animals (*Atharvaveda*, viii, 5, 11). According to Zimmer (quoted in Macdonell and Keith)[55] the wild animals are divided into five classes in a passage of *Atharvaveda* (xi, 2, 24, 25)—(i) those of the jungle; (ii) winged creatures like gander, eagle and other birds; (iii) amphibia including alligator, crocodile; (iv) fish; and (v) insects and worms. They are also classified into those which can hold with hand (*hastādanap*), and those which grasp by the mouth (*mukhadanap*; *see Taittirīya Saṃhitā*, vi, 4, 5, 7; *Maitrāyaṇi Saṃhitā*, iv, 5, 7). Another division is into biped (*dvipad*) and quadruped (*catuṣpad*; *see Ṛgveda*, iii, 62, 14; *Atharvaveda*, iii, 34, 1).

Keswani[56] contends that Aristotle's (384–332 B.C.) *Scala Naturae* which is considered as the earliest scientific classification of animal kingdom actually never occurs in any of his writings and has been 'somewhat forcibly extracted out of Aristotle's text'.[57] However, in ancient Vedic texts the living things are classified into three categories according to their mode of origin (*Chāndogya Upaniṣad*, vi, 3, 1). These are *aṇḍaja* (egg-born), *jīvaja* (born from the womb), and *udbhija* (propagated by sprouts). However, in *Aitareya Āraṇyaka* (ii, 6) the division is four-fold: (*a*) *aṇḍaja*, e.g. birds, snake, crocodile, fish, tortoise;

(*b*) *jaruja* or *jarāuja* (*Atharvaveda*, i, 12, 1), e.g. cattle, carnivorous beasts, men, etc.; (*c*) *udbhija* including all plants; and (*d*) *svedaja* which are sweat-born, e.g. insects, lice, flies, bugs. Although these classifications are of primitive type, one cannot deny that attempts for systematization of plants and animals were initiated at such an early age.

Interest in plant and animal forms was not lacking. The paintings and drawings stand as evidence to the accurate and beautiful representation of various parts. The constituents of plants are mentioned in *Taittirīya Saṃhitā* (ii, 5, 32; vii, 3, 19, 1) and *Vājasaneyī Saṃhitā* (xxii, 28). These are root (*mūla*), panicle (*tūla*), stem (*kāṇḍa*), twig (*valśa*), flower (*puṣpa*) and fruit (*phala*; *see Taittirīya Saṃhitā*, vii, 3, 20, 1; cf. *Ṛgveda*, i, 32, 5; *Atharvaveda*, x, 7, 38). *Śākhā* in the *Ṛgveda* and later works denotes the branch of a tree but *vaya* is more often used (*Ṛgveda*, ii, 5, 4; v, 1, 1; vi, 7, 6; 13, 1, etc.). *Valśa* stands for twigs, e.g. *śatavalśa* having a hundred twigs (*Ṛgveda*, iii, 8, 11; *Atharvaveda*, vi, 30, 2) and *sahasravalśa* having a thousand twigs. Hymns of *Atharvaveda* (viii, 7, 4)[58] give an elaborate division of plants. *Nyāgarodha* was used to characterize *Ficus indica* which sends down root-like structures from its branches. This morphological feature is frequently mentioned in the *Atharvaveda* (iv, 37, 4; v, 5, 5) and later *Saṃhitās* (*Taittirīya Saṃhitā*, vii, 4, 12, 1; *Vājasaneyī Saṃhitā*, xxiii, 13). The very fact that in Vedic times different kinds of stags, snakes and other animals were properly distinguished from one another, proves that such distinction was based on the study of morphological characters of the animals.

The absence of magnifying instruments was a great handicap and this seems to be responsible for lack of information about anatomy. However, references to gross internal features are frequently met with in the *Saṃhitās* and *Brāhmaṇas*. Since at the time of sacrifice, different parts of the body of the victim were dedicated to different deities, it was but natural to dissect the prey and make anatomical observations. A hymn of the *Atharvaveda* (x, 2) enumerates many parts of the body with remarkable accuracy. *Yajurveda Saṃhitās* also mention several constituents of the body. For example, *lomani* meant hair; *tvac* denoted skin; *māṃsa* signified flesh; *majjan* was marrow; *asthi* indicated bone; *yakṛt* implied liver; *kloman* spoke of lungs; *matasne* represented kidneys; *pitta* as gall; *antrāṇi* as entrails and so on (*see Vājasaneyī Saṃhitā*, xiv, 81–93; *Taittirīya Brāhmaṇa*, ii, 6, 4). *Śatapatha Brāhmaṇa* (x, 5, 4, 12; xii, 3, 2; 3, 4) records 360 bones in the human body. The bones of the skeleton of the horse are accounted in *Vājasaneyī Saṃhitā* (xxv, 1–9). In his *Upaniṣads and Modern Biology* Patwardhan[59] states that many more references could be given to show that *ṛṣis* had detailed knowledge of anatomical details of the body.

As compared to animals, plants were meagrely studied from anatomical viewpoint. Like the former, in the latter also *tvac* denoted skin or epidermis

and *lomani* constituted the hairs. In the *Brāhmaṇas vākala* stood for the inner bark of a tree (*Taittirīya Brāhmaṇa*, iii, 7, 4, 2; *Kauśitaki Brāhmaṇa*, x, 2); and *valka* for outer bark. In the *Ṛgveda* (vi, 3, 4) *dāru* (wood) is the term used to denote the softer outer part; and *majjā* was the name given to pith.[60] It may be recalled in this connection that Theophrastus of Eresus, a Greek scholar, who is credited for laying the foundations of present-day anatomy made a more or less similar attempt only in the third century before Christ when he described that plants are made up of bark (*phlois*), wood (*zylon*) and pith (*metra*), and that the stem is a fabric of veins, nerves and flesh.

It is believed that Aristotle was the first to investigate the development of animals from egg and embryo to the perfect state. But it is fascinating to find such a detailed description of the developmental stages of the human embryo from the time of fertilization to maturity in the Vedic literature. In fact, *Garbha Upaniṣad* gives a detailed day-to-day and then monthly description of differentiation of various stages in the development of human embryo, the various parts of which it is composed, even their number and weight.[61] According to Roy[62] the *Atharvaveda* and the *Bṛhadāraṇyakopaniṣad* refer to some surgical methods, herbal drugs and dietary preparations for the sterilization of man and woman, and to attempts made to control the sex, trait, temperament or complexion of the unborn child, although the scientific basis of these needs to be investigated. That sexual reproduction in higher plants and higher animals is quite similar, is mentioned in *Kaṭhopaniṣad*.[63]

Ancient pathologists and agriculturists were aware of sickness among men and cattle, and damages to crops due to plant diseases.[64] Much more was understood about animal diseases than those of plants. Scores of diseases have been enumerated in the Vedic literature. Suffice it to say that the diseases of plants as well as animals were diagnosed by their symptoms as is done even today, and usually general treatments were recommended to check or prevent these maladies. A hymn in *Atharvaveda* (vi, 50) refers to the destruction of corn by *tarda* (borer), *jabhya* (snapper), *upakvasa* (an insect injurious to seeds), *vyadvaras* (rodents) and others. Besides, injuries caused to seeds and young shoots due to moles, excessive rains and drought, and to the leaves of trees by *kapanā* (worm) are also referred to (*Ṛgveda*, v, 54, 6). Sour milk (curd) is repeatedly mentioned in the *Ṛgveda* (viii, 2, 9; ix, 87, 1) indicating thereby that they understood something about the *Lactobacilli*. Ainsworth[65] rightly points out that 'there are records of plant diseases in the Vedas'. Although various ceremonies and instructions are given in the Vedic texts to protect crops from insects, moths, birds and rats, and animals from diseases, most of them do not seem to be based on scientific methods.

The study of life in relation to environment probably commenced from the period of *Ṛgveda*. Climatic conditions have been well described under the term *ṛtu*. In one passage of *Ṛgveda* (x, 90, 6) it is subdivided into *vasanta*

(spring), *grīṣma* (summer), and *śarad* (autumn). A more usual division is into 5 seasons—*vasanta, grīṣma, varśā, śarad* and *hemantaśiśira* (*Atharvaveda*, viii, 2, 22; 9, 15; xiii, 1, 18 and so on). Sometimes 6 seasons are mentioned (*Atharvaveda*, vi, 55, 2; xii, 1, 36; *Taittirīya Saṃhitā*, v, 1, 5, 2; 7, 3; 2, 6, 1, etc.)—*hemanta* and *śiśira* being separated. Attempts at the classification on vegetation types were also made. The commonly stated categories are: forests, wastelands, grasslands or pastures and deserts. *Khila* or *Khilya* denoted the wasteland. *Gavyūti* in the *Ṛgveda* (i, 25; iii, 62, 16; v, 66, 3; vii, 77, 4) means grassland for the pasturing of cattle; and *Dhanvan* specified the desert (*Ṛgveda*, ii, 38, 7; iii, 45, 1). Shastry[66] believes that the *ṛṣis* 'were well aware of the different categories like aquatic, terrestrial as well as amphibious plants' (*Atharvaveda*, xi, 3, 6, 12; viii, 4, 47, 17). *Kiyambu* is the name of a water plant which grows, according to the funeral hymn in the *Ṛgveda* (x, 16, 13; *Atharvaveda*, xviii, 3, 6) near a place where the body of the dead was burned. A number of other plants are also described which are associated with particular type of situations and could easily be classified as plant indicators.

It is interesting to note that the study of plant physiology was not ignored. Reasonably correct knowledge existed on various vital phenomena like life, germination, assimilation, growth and movement in plants. Good deal of information also existed on human physiology and agricultural practices. *Mṛtyu* (death) is repeatedly mentioned in *Ṛgveda* (vii, viii, x). The natural death was considered by ageing (*Atharvaveda*, ii, 13, 2). Nagar[67] mentions that during the *Ṛgvedic* period blood was used for manuring as in the present day (red blood contains about 13·5 % nitrogen and traces of phosphoric acid). The importance of green manure prepared from the straw of barley, and sesame plants (*Atharvaveda*, ii, 8, 3) and natural manure of animals like cowdung (*Atharvaveda*, iii, 14, 3, 4; xix, 31, 3) was recognized to increase the productivity of land. According to Majumdar[68] 'The Vedic people had some knowledge of the manufacture of food, the action of light on the process and storage of energy in the body of plants' (*Ṛgveda*, viii, 43, 9; ii, 1, 14).

A verse from the *Taittirīya Upaniṣad* (ii, 1) distinctly shows that the idea of evolution was familiar: 'From the *Ātman* the ether was produced; from the ether air; from the air fire; from the fire water; from the water earth; from the earth plants; from the plants man'. 'The Vedic Thinkers believed that plants had preceded animals particularly man, in the scale of arrival of living beings on earth. This is indicated clearly in a hymn of the *Ṛgveda* (x, 97, 1).'[68] According to Patwardhan[69] 'In *Praśna* (3–3) it has been distinctly stated that life on this earth had its beginning in the slimes collected on the surface of the primeval oceans due to the action on them of the Cosmic rays of the Sun'.

Animal and plant products were put to innumerable economic uses. The skin of goat, antelope, tiger was used for making dresses; sheep's wool for clothing and filtering juice; boar's skin for making footwear; rhinoceros'

hide for chariot covering; flesh for eating; and bones for making implements. Frequent mention of ropes implies the existence of several fibres—cultivated or wild.[70] Thus, the Vedic people not only investigated the problems and mysteries of nature but also contributed sufficiently to the systematic study of plants and animals.

The Post-Vedic Era and the Classical Age

Although the foundations of some biological ideas were laid in the Vedic times, these were greatly modified and improved later. *Caraka* and *Suśruta Saṃhitās* corroborate this statement. Nevertheless, the sciences of medicine and agriculture were more advanced than biology. The plants and animals were classified mainly in the interest of *Materia Medica*.[71, 72] Generally two names were given to a plant—one based on its external features and meant for the layman and the other indicating its medicinal properties and intended for the physician. In Sanskrit nomenclature a method similar to the present-day binomial system was in vogue. Plant names were associated with distinguished personalities, their special property, characteristic morphological features or habitat.[73, 74] One comes across a host of terms for describing different parts of a plant, flower, fruit and seed. References to gross anatomy are also met with. Information on photosynthesis, respiration, transpiration, manuring and crop rotation in plants; and metabolism, circulation of blood, nervous and reproductive systems and embryogenesis in animals existed in a small way. Attempts were made in these *Saṃhitās* to answer questions relating to transmission of specific characters, and the similarities between offsprings and parents. All organs were considered to be simultaneously present in the fertilized ovum which unfolded in a particular order.[75] Symposia and discussions were held on various biological problems like the growth of the foetal limbs, use of emetic nut, study of practical anatomy and so on.[76]

Ideas about progressive evolution and reversions are found in the *Sāṅkhya* philosophy. According to Sen,[77] three principles pertaining to organic evolution have emerged from an analysis of this concept. These are: (1) 'evolution is not purposive in plants', (2) 'it is a continuous process', and that (3) 'vegetation is running down through the last few ages'.

Buddhism and Jainism offered no bars to the development of science. Buddha's own ideas regarding evolution of the earth are praiseworthy.[78] The famous taxonomic studies of *Jīvaka* at Taxila were also made in the Buddhist period.[79, 80] Apart from other disciplines, the universities of Nalanda and Taxila were imparting instructions in biology as well. The *Vinaya-Piṭaka* shows that Indians were familiar with diseases affecting rice fields.[81] Preparations to remove barrenness and fertility were given by monks to women. *Aṇḍabhūta Jātaka* indicates that methods were known for the determination of sex of the unborn child.[82] According to Mehta[83] the

knowledge of animals (their diseases and cures), trees, fruits, medicine and surgery was 'far advanced in the *Jātaka* days'. Mangoes, roseapple, jack fruit, bread fruit, palm fruit, cucumbers and sugarcane were in use. Various kinds of crops; spices like pepper, mustard, dry ginger, garlic; and oilseeds like castor were grown. Dairy farming had made considerable progress.[84] *Sati-patthana Sutta* in the *Majjhima Nikāya* bears ample evidence to the development of knowledge of human anatomy. Gosala, the leader of the *Ajivikas*, founded his religion on the principles of biology in the most comprehensive sense of the term, with the elements of botany, zoology, geology, anatomy, physiology and embryology coming within its scope. These elements were further developed by the Jainas in their *Āgama*.

Reference may also be made here of the scanty botanical and zoological information contained in the *Mahābhārata* and *Rāmāyaṇa*—the latter has been analysed by Roy.[85] Sugarcane (*Saccharum officinarum*) is mentioned in the Hindu mythology. Singer *et al.*[86] believe that it is probable that it originated in India, 'the name *Saccharum* appears to come from the Sanskrit word *Karkara*. The European invaders accompanying Alexander the Great (*c.* 325 B.C.) were first to see the sugarcane. Nearchos, who was in the campaign, described it as a grass which produced honey without the help of bees . . . In ancient Mesopotamia, it appears to have been unknown'.

Kauṭilya's *Arthaśāstra* gives indications that the effect of temperature on grain germination, vegetative propagation of sugarcane by various treatments, and usefulness of cowdung and bones as manure was understood. These manures obviously contain all the necessary ingredients for the nutrition of plants, namely nitrogen, phosphorus, calcium and potash.[87] Cattle breeding was undertaken, and model bulls and horses supplied to people for crossing purposes. Castration was prevented.

Gupta[88, 89] has thrown substantial light on the insects, birds and their seasonal life in the works of Kālidāsa. That Manu believed in the hereditary transmissibility of characters is fully brought out by Bose.[90] The influence of both parents in the determination of characters of the offspring has been discussed in *Manu Saṃhitā*.

In the Gupta Age the spirit of enquiry still dominated. There exist a few descriptive accounts wherefrom information on a large number of plants and animals can be gathered. It was near about this time that Parāśara through his *Vṛkṣāyurveda*[91] and Varāhamihira through *Bṛhat Saṃhitā*[92] advanced our knowledge of natural sciences, especially about the diagnoses and remedies of plant diseases. Discovery of Bower's MSS. proved a good source of information about medicine and biology. The study of *Saṅgam* literature in the Tamil country made by Srinivasa Rao[93] has proved that this literature is rich in the descriptive accounts of a large number of animals and also mentions several interesting facts of their natural history, habits, and ecological

distribution. *Kṛṣi-Parāśara* and *Amarakośa* too provide enlightenment on various aspects of agriculture, and on plant and animal life.[94] But it would appear that hardly any new biological concepts were formulated during this period.

Medieval Biology in India

Like other sciences, the inquisitiveness for exploration in biology too began to decline in the early medieval period. This was mainly due to the sway of orthodox religion, feudalism and political insecurity caused by the Muslim and European invasions. Śukrācārya made a study of the Indian flora mainly from the utilitarian viewpoint.[95] Viśvakarmā in his *Bhuvana-pradīpa* (a *sīlpaśāstra*) gave a primitive classification of soil into *Brāhmaṇa*, *Kṣatriya*, *Vaiśya* and *Śūdra* types; based on their colour, smell, taste, and time taken by sesamum seeds to germinate in them.[96] Cakrapāṇi, the chief interpreter of Caraka; Hemādri and Aruṇdatta, the leading commentators of Vāgbhaṭa;[97] and Haṇsadeva through his *Mṛgpakṣiśāstra* contributed little novel about natural sciences. However, *Śāraṅgdhara's Paddhati*, an encyclopaedic Sanskrit treatise of the thirteenth century, is outstanding. A small chapter in it entitled 'Upavana-vinoda' deals with several aspects of plants, especially the arbori-horticultural. Elaborate attention is paid to the classification of plants, selection of soil, sowing of seeds, planting and watering methods, construction of green house, nutrition of plants, care of their health and treatment of diseases, as well as production of botanical marvels. According to Majumdar[98] the accounts of new creations in plant life as given by Varāhmihira and Śāraṅgdhara are of great significance when compared with the works of Luther Burbank of the modern times. Dhanvantari's *Rājanighaṇṭu* and Bhāvamiśra's *Bhāvaprakāśa* are primarily of medicinal importance but contain information on the names, descriptions and morphological features of plants together with classification based on their chemical nature, pharmacological and economic uses and external characters.

As warriors, sportsmen and naturalists the Muslim kings maintained large fleets of pedigree animals and excellent pleasure gardens. 'Tuzuk-i-Jahangiri' contains descriptions of about 36 species of animals and 57 plants. Their distinctive characters, ecology, anatomical notes, geographical distribution, local names, weights and measurements are mentioned. References to the role of rats in plague, manufacture of beverages and rose scents are also given. Scientific classification was not known to Jahangir but he did indicate affinities between two or more animals which are presently classified together in the same family or in good many instances under the same genus. In botany, his interests were primarily horticultural. Awareness of types of inflorescences, pollination, and methods of fruit preservation is also discernible.[99] There is good evidence of breeding trials and hybridization of goat and deer. Jahangir carried out such experiments between the Ibex and the Barbary goat, and

Abul Fazl has mentioned the maintenance of regular deer studs to breed blackbuck to be trained as decoys for catching and hunting wild antelope.[100]

A renewed interest in biology, however, grew up with the advent of the Portuguese. The first contribution *Coloquios dos simples e drogas he cousas medicinais da India compostos pelle Doutor Garcia de Orta* was made in 1563 in two volumes, and contains descriptions of a large number of drug plants. Later, Christobal Acosta wrote the second illustrated book entitled *Tractado de las drogas y medicinas de las Indias Orientales.* Incidental references to Indian plants and animals have also been made in a few travel books by Varthema, Paludanus and others.[101] The best presentation of the Portuguese to India was the introduction of new plants like the custard apple, pineapple, guava, chillies, cashewnuts and perhaps tobacco and potato.

The Dutch, who followed the Portuguese, showed considerable interest in plants and animals because in their own country the universities were equipped with gardens and at Leiden they had even a hothouse to grow tender plants. In 1676, Heinrich van Rheede tot Drakenstein, the Dutch Governor of Malabar, made a large collection of plants through a local brahmin, sent them to Cochin to be sketched by an artist, and described them in Latin in the famous *Hortus Malabaricus* in 12 richly illustrated volumes having 794 plates. This work is important because in Linne's *Species Plantarum* the nomenclature of Indian plants is based on this compilation. The credit for introducing Linnaeus' binomial system of nomenclature in India goes to his Danish pupil, Johan Gerhard Koenig, who also wrote an account of the white ants of India in 1779. Other Danish missionaries like Heyne, Klein, Rottler collected plants, made herbarium sheets, exchanged specimens and sent plants to Europe for naming and describing them. One, therefore, frequently comes across the names of these authors at the end of a large number of Indian plants. All botanists of this time were expected to understand zoology and zoologists to have the knowledge of botany[102] so that equally commendable publications appeared in both these fields.

Apart from the Danes, the French were also collecting large number of plants and sending them to Paris to enrich their National Museum. Sonnerat, although a zoologist, was stationed at Mahe, Pondicherry, Surat and Ceylon at different times, and accumulated a good number of specimens. Lamarck, Poiret and De Candolle profited greatly from these collections and studied and described numerous plants received from the French colonies.

A fresh impetus to biological studies in the eighteenth century came from the British who through the East India Company had by now secured a firm hold in our country. The most spectacular event was the establishment in 1787 of the Royal Botanic Gardens at Calcutta which in the nineteenth century became one of the most important centres of botanical research in the tropics. Lt.-Col. Kyd introduced as many as 300 plants to this garden. He

also wrote the *Flora Indica, The Plants of the Coast of Coromandel*, and *Hortus Bengalensis*. His immediate successor, Williams Roxburgh, made his first contribution entitled *Plantae Coromandelianae* in 1795 and also compiled a catalogue of plants growing in the garden at that time. His immense zeal, hard work and real scientific attitude earned him the title of the 'Father of Indian Botany'.

Another landmark was the beginning in 1784 of the Asiatic Society which was founded by Sir William Jones, a learned judge and a great botanist and orientalist. The word 'Bengal' was added to it much later. For more than a century the *Journal of the Asiatic Society of Bengal* published papers on natural history. Little was, however, learnt about the plant and animal life lying in the sea.

Thus, the biological knowledge during the medieval period mainly grew as a result of the efforts of European missionaries, medical men, and army officers. However, their contributions are hardly comparable with the significant achievements being made at that time in Europe on classification of plants by John Ray, Bachmann and Tournefort, and on anatomical structure by Grew and Malpighi. Similarly they were much behind their contemporaries abroad in the study of reproduction, physiology and even agriculture and horticulture for that matter.

Source Materials, Problems and Remedies

Most of the earlier sources of biological ideas, which can be profitably tapped for bringing to light some of the shrouded mysteries of the past, were written in Sanskrit, the 'Latin' of India. However, other languages like Prākrit (vernaculars), Tamil (south Indian language), Pali (the sacred language of the Buddhist scriptures), and Ardha-Māgadhi (the sacred language of Jains) have also helped to perpetuate India's achievements. According to Filliozat[103]: 'All in all, Indian languages, and particularly Sanskrit, influenced the ancient scientific literature of upper Asia, of Tibet and Mongolia and of the Cambodian peninsula—Burma, Thailand, Laos, Cambodia and Indonesia—much as Greek literature, imitated, copied or translated into Latin, Syriac or Arabic, influenced the thought of all Western Countries'. Although the importance of critical examination of such primary sources in various languages cannot be denied, it would save considerable time and effort if secondary sources too are studied critically and objectively. After all well-known experts have very ably interpreted the primary sources and expressed their viewpoint. Besides, mythological stories, folklore, epic poems, medicinal treatises, ancient manuscripts, sacred books of the Buddhists, early texts of Jains, and national archives unmistakably provide valuable data. Some of these have already been examined by earlier workers, but the biological skill of our ancestors has not yet been fully explored from these sources.

While the selected references listed at the end of this paper may prove useful to the future investigator, attention is also drawn to the bibliography in Majumdar's book entitled *Vanaspati*.[104] More comprehensive is the chapter on sources in Kashikar's English translation of Jolly's work designated as *Indian Medicine*.[105] It takes into account the entire literature from the Vedas to the *Bhāvaprakāśa*. Several works cited therein must as well be examined thoroughly for conducting research in ancient biology. This list has been significantly improved and enlarged by the inclusion of 'Addenda' and the 'Supplementary Notes' (pp. 184–208).[105] It would be futile to rewrite all those references here, but suffice it to say that to the student of ancient Indian botany as well as zoology, this enumeration is of great reference value.

Mention may be made here of some special topics on which detailed studies could be undertaken. These are: Plants and animals in ancient scriptures, treatises, texts, epics, or civilizations; Biological concepts in the Vedas; Contributions of Charaka and Suśruta to the advancement of our knowledge of Biology; Identification of plant and animal motifs on seals, tablets, edicts, temples, mosques and historical monuments; Archaeological evidence and biology; Gardens and Parks in ancient India; Biology in Muslim India; Sanskrit nomenclature of plants and animals; Manu's philosophy of life and its probable biological significance; Plant and animal diseases of the hoary past; Buddha's ideas on evolution. Investigations on the history of development of various disciplines analogous to the present-day morphology, anatomy, embryology, physiology, evolution and heredity would also reveal interesting information. Further examination of works like the *Vṛkṣāyurveda* would greatly enlighten. All these and a host of other problems are awaiting exploration and could be pursued with profit.

It may be worth while to dwell on the obstacles and perplexities that confront a worker engaged in the task of solving knotty problems of the ancient texts. These texts as such are tough to interpret and a completely satisfying and faithful analysis is well-nigh unattainable. There are difficulties in verifying the Latin synonyms of plants and animals mentioned in older works and in identifying motifs on seals and edicts, temples and mosques, and places of historical interest. It is rare that a scholar of History of Biology can combine a good insight into botany and zoology with Sanskrit or other oriental language and be a reasonably satisfactory historian too. Generally one suffers due to the lack of knowledge of one field or the other. Hence, there has to be team-work in which a botanist or a zoologist, a linguist, and a historian cooperate to unravel biological enigmas of the past. In such a collaboration, emphasis has to be laid on proper sifting of the data with an unprejudiced mind, in a purely scientific spirit, rather than upholding a view on meagre or insufficient ground. The workers should unhesitatingly express

doubt, plead ignorance or suggest alternative possibilities and explanations without the fear of being classified as unpatriotic.

To remedy the handicaps of the research worker arising due to paucity of funds, and to give impetus to investigations on the history of biology, it is desirable to institute scholarships and fellowships. Funds should be freely provided by organizations like the UGC, CSIR, NISI, Archaeological department, Botanical and Zoological Surveys of India for schemes of research, procurement of rare manuscripts, purchase of books, and travel so that the investigator could visit historical places, museums and libraries from where it is not always possible to move the rare documents or specimens. Many scholars experience difficulty in the publication of their papers. This has been partly overcome by the recent introduction of *Indian Journal of History of Science*. But the length of the article and the preparations of blocks and halftones of the illustrative material sometimes involve high expenditure, and suitable grants need to be provided for this purpose. The universities should not only introduce the teaching of history of biology (with special emphasis on Indian contributions) to students of botany and zoology at the undergraduate level (wherever it is not done), but also permit and encourage the registration of candidates for M.Sc and Ph.D. degrees if they take up any research projects on subjects dealing with history of botany or zoology. The Anthropological, Botanical and Zoological Surveys of India should create small cells within their organizations for such studies. Arranging short-term courses, holding of summer schools, seminars and symposia, and sanctioning sabbatical leave to interested teachers would also give a stimulating push in the right direction.

With more and more facilities, monetary assistance, availability of manuscripts and expert linguists, and above all the governmental patronage, a poignant atmosphere could be created for carrying out researches on the achievements and trends of thought of our ancestors.

ACKNOWLEDGEMENTS

I express profound reverence to the late Professor P. Maheshwari, FRS, who initially inspired me in the field of History of Botany, evinced great interest in my work and encouraged me to continue such studies.

I am grateful to Dr. B. V. Subbarayappa of the National Institute of Sciences of India, for his ready help in procuring several books and texts of old manuscripts. He has been most liberal in giving his suggestions and without these the manuscript could have hardly obtained this shape. The authorities of the Delhi University Library provided all facilities. Mr. G. A. Sastri, Mr. Sher Singh and Mr. Jagdish Rai Sikri showed me unfailing courtesy and were extremely helpful. I am specially indebted to my wife, Nirmal, who herself a botanist, read the manuscript critically and rendered material help for its improvement.

References

[1] Filliozat, J., Ancient Indian Science. In: Taton, R. (ed.), *Ancient and Medieval Science*, Basic Books Inc., New York, p. 133, 1957.

[2] Burkill, I. H., *Chapters on History of Botany in India. Bot. Surv. India*, p. 1, 1965.

[3] Majumdar, G. P., *Vanaspati*. Univ. Press, Calcutta, 1927.

[4] Seal, B. N., *The Positive Sciences of the Ancient Hindus*, Moti Lal Banarasi Dass, Delhi, 1958.

[5] Hora, S. L., Knowledge of the ancient Hindus concerning fish and fisheries of India. I. References to fish in Arthasastra. (*ca.* 300 B.C.). *Jl R. Asiat. Soc. Beng.* (Science), **14**, 7–10, 1948;
Knowledge of the ancient Hindus concerning fish and fisheries of India. II. Fishery legislation in Ashoka's pillar edict V (246 B.C.). *Jl R. Asiat. Soc. Beng.* (Letters), **16**, 43–56, 1950;
Zoological knowledge with special reference of fish and fisheries in India before 225 B.C. *Archiv. Int. Hist. Sci.*, **15**, 405–412, 1951;
Maintenance of irrigation tanks through fishery revenue in ancient India. *Jl R. Asiat. Soc. Beng.* (Letters), **17**, 41–50, 1951;
Appendix III — Chronology Committee. In: Symposium on History of Sciences in South Asia. *Proc. natn. Inst. Sci. India*, **18**, 331, 1952.

[6] Srinivasa Rao, H., History of our knowledge of the Indian fauna through the ages. *J. Bombay natn. Hist. Soc.*, **54**, 251–280, 1957.

[7] Maheshwari, P., and Kapil, R. N., A short history of botany in India. *J. Univ. Gauhati*, **9**, 1–34, 1958.

[8] Hora, S. L., *Op. cit.*, 1952.

[9] Sankalia, H. D., *Prehistory and Protohistory in India and Pakistan*. Univ. Bombay, 1962.

[10] Piggott, S., *Prehistoric India*. Penguin Books, Middlesex, p. 33, 1950.

[11] Wadia, D. N., The geological background of India History. In: Majumdar, R. C., and Pusalker A. D. (eds.), *The Vedic Age*, p. 83, 1951.

[12] ———— *Op. cit.*, p. 84.

[13] Wheeler, M., *Early India and Pakistan*. Thames and Hudson, London, p. 61, 1959.

[14] Sankalia, H. D., Paleolithic, Neolithic and Copper Ages. In: Majumdar, R. C., and Pusalker A. D. (eds), *The Vedic Age*, p. 134, 1951.

[15] ———— *Op. cit.*, p. xix, 1962.

[16] ———— *Op. cit.*, p. 136, 1951.

[17] Zeuner, F. E., Cultivation of plants. In: Singer, Charles, Holmyard, E. J., and Hall A. R. (eds), *A History of Technology*, Oxford, p. 363, 1954.

[18] Furon, R., The dawn of science: prehistoric beginnings. In: Taton, R. (ed.), *Ancient and Medieval Science*, p. 8, 1957.

[19] Piggott, S., *Op. cit.*, p. 13, 1950.

[20] Hawkes, Jacquetta, Prehistory. In: Hawkes, Jacquetta and Woolley, L., *History of Mankind—Cultural and Scientific Development. I. Prehistory and the beginnings of civilization*, 3–256, George Allen and Unwin Ltd., London, p. 255, 1963.

[21] Furon, R., *Op. cit.*, p. 6, 1957.

[22] Mackey, E., Ivory, shell, faieme, and other objects of technical interest. In: Marshall, J. (ed.), *Mohenjo-daro and the Indus Civilization*, p. 586, 1931.

[23] Reed, H. S., A Short History of the Plant Sciences. Chronica Botanica, Waltham, p. 8, 1942.

[24] Majumdar, G. P., The history of botany and allied sciences (agriculture, medicine, arbori-horticulture) in Ancient India (*c.* 2000 B.C. to A.D. 100). *Arch. Int. Hist. Sci.*, **14**, pp. 100–133, 1951.

[25] Pusalker, A. D., The Indus Valley Civilization. In: Majumdar, R. C., and Pusalker, A. D. (eds.), *The Vedic Age*, pp. 169–198, 1951.

[26] Reed, H. S., *Op. cit.*, p. 8, 1942.

[27] Mackay, E., Seal impressions, and copper tablets with tabulation. In: Marshall, J. (ed.), *Mohenjo-daro and the Indus Civilization*, pp. 390–391, 1931.

[28] Zeuner, F. E., *Op. cit.*, pp. 373–374, 1954.
[29] Ghosh, S. S., Study of an ancient fabric and its identification. *Bull. Hyderabad Arch. Surv.*, **17**, 1, 1953.
[30] Piggott, S., *Op. cit.*, p. 155, 1950.
[31] Mackay, E., Household objects, tools and implements. In: Marshall, J. (ed.), *Mohenjo-daro and the Indus Civilization*, p. 468, 1931.
[32] Zeuner, F. E., *Op. cit.*, pp. 373–374, 1954.
[33] Reed, H. S., *Op. cit.*, p. 13, 1942.
[34] Coonen, L. P., Biology in Old China. *The Biologist*, **36**, 3–12, 1953.
[35] Chowdhury, K. A., *Wood Anatomy*. Aligarh Muslim Univ. Press, pp. 26–35, 1968.
[36] Chowdhury, K. A., and Ghosh, S. S., Plant remains from Harappa. *Ancient India*, **7**, p. 17, 1951.
[37] Chowdhury, K. A., *Op. cit.*, p. 27, 1968.
[38] Pusalkar, A. D., *Op. cit.*, p. 174, 1951.
[39] Piggott, S., *Op. cit.*, p. 135, 1950.
[40] Wheeler, M., *Op. cit.*, p. 110, 1959.
[41] Mackay, E., Games and toys. In: Marshall, J. (ed.), *Mohenjo-daro and the Indus Civilization*, p. 551, Arthur Probsthain, London, 1931.
[42] Seymour Sewell, R. B., and Guha, B. S., Zoological remains. In: Marshall, J. (ed.), *Mohenjo-daro and the Indus Civilization*, pp. 669–672, 1931.
[43] Srinivasa Rao, H., *Op. cit.*, 1957.
[44] Nath, Bhola, Animal remains from Rangpur. In: Rao, S. R., Excavation at Rangpur and other explorations in Gujrat, *Ancient India*, **18** and **19**, p. 155, 1962–1963.
[45] Ghosh, S. S., and Lal, Krishna, Plant remains from Rangpur. In: Rao, S. R., Excavations of Rangpur and other explorations in Gujrat, *Ancient India*, **18** and **19**, pp. 172–173, 1962–1963.
[46] ——— Further records of *Oryza* spp. from Ancient India. *Indian Forester*, 87, p. 295, 1961.
[47] Reed, H. S., *Op. cit.*, p. 9, 1942.
[48] Nordenskiold, E., *The History of Biology—A Survey*. Tudor Publishing Co., New York, p. 6, 1928.
[49] Durant, W., *Our Oriental Heritage*. Siomon and Schuster, New York, pp. 181–182, 1954.
[50] Macdonell, A. A., and Keith, A. B., *Vedic Index of Names and Subjects*. I and II. John Murray, London, 1912.
[51] Majumdar, G. P., *Op. cit.*, pp. 234–254, 1927.
[52] Aiyer, A. K. Y. N., *Agriculture and Allied Arts in Vedic India*. Bangalore Press, Bangalore, pp. 32–45, 1949.
[53] Shastry, V. R., Science in the Vedas. *Bull. natn. Inst. Sci. India*, No. 21, p. 102, 1963.
[54] Srinivasa Rao, *Op. cit.*, pp. 259–261, 1957.
[55] Macdonell, A. A., and Keith., A. B., *Op. cit.*, p. 510, 1912.
[56] Keswani, N. H., The concepts of generation, reproduction, evolution and human development as found in the writings of Indian (Hindu) scholars during the early period (up to A.D. 1200) of Indian History. *Bull. natn. Inst. Sci. India*, No. 21, p. 208, 1963.
[57] Singer, C., *A short History of Anatomy from the Greeks to the Harvey*. Daver, New York, p. 209, 1957.
[58] Bloomfield, M., *Hymns of the Atharvaveda*. Motilal Banarasi Das, Delhi, 1964.
[59] Patwardhan, K. A., *Upaniṣads and Modern Biology*. Popular Book Depot, Bombay, p. 44, 1957.
[60] Majumdar, G. P., *Op. cit.*, p. 103, 1951.
[61] Weber, A., *The History of Indian Literature*. Kegan Paul, Trench, Trübner and Co., London, p. 160, 1892.
[62] Roy, Mira, Methods of sterilization and sex-determination in the *Atharvaveda* and the *Bṛhadāraṇyakopaniṣad*. *Indian J. Hist. Sci.*, **1**, 91, 1966.
[63] Patwardhan, K. A., *Op. cit.*, p. 59, 1957.
[64] Weber, A., *Op. cit.*, p. 69, 1892.

[65] Ainsworth, G. C., Historical Introduction to Mycology. In: *The Fungi*. I. Academic Press, New York, pp. 3–20, 1965.
[66] Shastry, V. R., *Op. cit.*, p. 102, 1963.
[67] Nagar, B. R., Manuring in ancient India. *Bull. natn. Inst. Sci. India*, No. 21, p. 131, 1963.
[68] Majumdar, G. P., *Op. cit.*, p. 104, 1951.
[69] Pathwardhan, K. A., *Op. cit.*, p. 35, 1957.
[70] Aiyer, A. K. Y. N., *Op. cit.*, p. 23, 1949.
[71] Rāy, P., and Gupta, H. N., *Caraka Saṃhitā* (A Scientific Synopsis). National Institute of Sciences of India, New Delhi, pp. 26 and 30, 1965.
[72] Bhishagratna, K. L., The *Suśruta Saṃhitā* (An English translation based on original Sanskrit text). I, II and III. Chowkhamba Sanskrit Series Office, Varanasi, p. 705, 1963.
[73] Majumdar, G. P., *Op. cit.*, 1927.
[74] Maheshwari, P., and Kapil, R. N., *Op. cit.*, 1958.
[75] Seal, B. N., *Op. cit.*, 1958.
[76] Satya Prakash, *Founders of Science in Ancient India*. Res. Inst. Ancient Sci. Studies, New Delhi, 1965.
[77] Sen, J., Some concepts of organic evolution of the ancient Hindus. *Bull. natn. Inst. Sci. India*, No. 21, 184–188, 1963.
[78] Majumdar, G. P., *Botany in India—past and present*. The Cultural Heritage of India, Sri Ram Krishna Centenary Memorial, Vol. III. Calcutta, pp. 430–431.
[79] Das, S. K., *The Educational System of the Ancient Hindus*. Mitra Press, Calcutta, pp. 218–222, 1930.
[80] Maheshwari, P., and Kapil, R. N., *Op. cit.*, p. 2, 1958.
[81] Majumdar, B. B., Literary sources of history of cultivation of rice and its varieties. *Symp. Hist. Sci. India* (abstracts), *Natn. Inst. Sci. India*, New Delhi, pp. 24–25, 1968.
[82] Cowell, E. B., *The Jātaka or Stories of the Buddha's Former Births*. Luzac and Co., London, No. 62, p. 151, 1957.
[83] Mehta, N., *Pre-Buddhistic India*. Examiner Press, Bombay, pp. 309–311, 1939.
[84] Law, B. C., *India as described in Early Texts of Buddhism and Jainism*. Luzac and Co., London, 1941.
[85] Roy, Mira, Scientific information in the *Rāmāyaṇa*. *Bull. natn. Inst. Sci. India*, No. 21, 58–66, 1963.
[86] Singer, C., Holmyard, E. J., and Hall, A. R., *A History of Technology*. Clarendon Press, Oxford, pp. 370–371, 1954.
[87] Choudhury, Mamata, Science and society in the *Arthaśāstra* of Kautilya. *Bull. natn. Inst. Sci. India*, No. 21, pp. 36–46, 1963.
[88] Gupta, C. S., Insects in the literature of Kalidasa. *Bull. natn. Inst. Sci. India*, No. 21, pp. 145–172, 1962.
[89] ———— Seasonal life of birds in the works of Kalidasa. *Symp. Hist. Sci. India* (abstract), National Institute of Sciences of India, New Delhi, p. 68, 1968.
[90] Bose, N. K., Theory of heredity in the *Manu Saṃhitā*. *Bull. natn. Inst. Sci. India*, No. 21, pp. 226–227, 1963.
[91] Majumdar, G. P., *Op. cit.*, pp. 108–109, 1951.
[92] Biswas, K., History of Botany of early and medieval periods. *Bull. natn. Inst. Sci. India*, No. 21, pp. 189–195, 1963.
[93] Srinivasa Rao, H., *Op. cit.*, pp. 263–268, 1957.
[94] Law, B. C., *Op. cit.*, 1941.
[95] Biswas, K., *Op. cit.*, 1963.
[96] Bose, N. K., *Canons of Orissa Architecture*. R. Chatterji, Calcutta, p. 47, 1932.
[97] Filliozat, J., Science in Medieval India. In: Taton, R. (ed.), *Ancient and Medieval Science*, Basic Books Inc., New York, p. 425, 1957.
[98] Majumdar, G. P., *Upavana-vinoda* (A Sanskrit treatise on Arbori-horticulture), Indian Res. Inst., Calcutta, p. 31, 1935.
[99] Alvi, M. A., and Rahman, A., *Jahangir—the Naturalist*. National Institute of Sciences of India, New Delhi, 1968.

[100] Srinivasa Rao, H., *Op. cit.*, p. 271, 1957.
[101] Burkill, I. H., *Op. cit.*, pp. 4–6, 1965.
[102] ———— *Op. cit.*, p. 13, 1965.
[103] Filliozat, J., *Op. cit.*, p. 133, 1957.
[104] Mazumdar, G. P., *Op. cit.*, pp. 226–230, 1927.
[105] Jolly, J., *Indian Medicine* (English translation by Kashikar, C. G.), Poona, 1951.