Chapter Two Balance of Nature

Ecology and Economics, are related scientific disciplines which are concerned with energy interactions and relationships. The former is mainly concerned with the general biosphere, while the latter specialises in the affairs of the human specie.

The division between the general and the specific, is common in science. The general disciplines of Zoology and Ethology, have their specific counterparts in Physiology and Psychology.

All six of these disciplines relate to the totality of the biosphere; but this chapter will concentrate on the mainstream conventions of Ecology and Ethology. The former covers the internal and external environments, which affect specie evolution; while the latter concentrates on the internal and external stimuli, which affects the current behaviour of specie.

This is a selective view to prepare the reader for the topic of human evolution.

Ecology

Apart from the evolution of life itself, the most important development in the biosphere was photosynthesis.

Photosynthesis is unique to green plants, some red and brown algae, and a few bacteria. It enables organisms to convert the Sun's light into chemical energy, which can be stored for future use.

The absorption of light energy requires the presence of pigments, which are contained in chloroplasts in the cells of the organism. The most important pigments are the chlorophylls, which give plants their green colour. Clusters of chlorophyll molecules, called quantosomes, are stacked on membranes within the chloroplast. Light 'excites' the chlorophyll molecules, causing the emission of high energy particles. These help to create new molecules, which are capable of storing chemical energy.

To appreciate the effect of this microscopic reaction on the biosphere, it is desirable to examine the process in detail.

Mechanics of Photosynthesis

The first part of the photosynthesis process is called the light reaction. This takes place in the quantosomes, and involves the conversion of radiant energy into chemical energy, and simultaneous splitting of water molecules.

Each water molecule is a compound of hydrogen and oxygen atoms. When these atoms divide, the oxygen escapes from the chloroplast and eventually passes into the atmosphere. The remaining hydrogen atoms are taken up by a hydrogen receptor, called N.A.D.P. (Nicotinamide Adenine Dinucleotide Phosphate).

The second part of the process is called the dark reaction. It takes place in a watery fluid which surrounds the chloroplast membranes. The chemical energy produced by the light reaction combines with carbon dioxide and the hydrogen of N. A. D. P., to form a new molecule containing carbon, oxygen and hydrogen.

This results in the production of sugar, which can then be converted into other sugars, starches, and carbohydrates.

Photosynthesis requires radiant energy and various chemical compounds. The radiant energy is eventually lost by the biosphere, in the form of heat. However, the chemical compounds can be continually recycled, and this allows the process to be repeated ad infinitum.

Cycle of Elements

The most important of the recycled elements are hydrogen and oxygen, in the form of water; and carbon, nitrogen, calcium, sulphur, phosphorus, and metal salts.

All the chemical elements present in organisms also occur in the non-living part of the Earth's crust, but in different proportions. Living organisms contain relatively more oxygen, carbon, hydrogen and nitrogen than inorganic matter, but less potassium, sodium, iron and silicon. All these materials are recycled through the biosphere either as elements, or as part of more complex compounds. All are important, in some way, for the maintenance of life

Water makes up about 70% of the weight of most plants and animals. Land plants gain their water from rain, snow, hail etc. , and lose it through transpiration, or evaporation. In tropical areas, the evaporation rate may be such that even with moderate to heavy rainfall there may be too little for some types of plants. In temperate areas, where the evaporation rate is lower, light rainfall can be biologically more effective than three times as much in tropical zones.

Carbon is obtained from the atmosphere, and water. It is returned by respiration; or decomposition of waste products; or through the decomposition of the organisms themselves, when they die.

Nitrogen cannot be obtained directly from the atmosphere. It is either transferred by nitrogen-fixing bacteria, which live within the root structures of certain plants, or it is taken up directly through the roots of plants in the form of soluble compounds. These compounds may arise through the agency of lightning, or the decomposition of dead organisms. Nitrogen compounds form an important part of proteins. In this form, it is transferred to animals, either when they eat protein-rich plant foods, or other animals.

Other important elements, like calcium and sulphur, are cycled in a similar way The former can be taken up by land plants through their roots. When the plants are eaten by animals they utilise it in their skeletal structures in the form of bones, teeth, or shells. When such animals die, the action of weak carbonic acid in rainwater leads to the break-up of the calcium compounds, releasing both calcium and carbon back into the biosphere.

Apart from its vital role in photosynthesis, water provides structural support for lake and ocean organisms. Air, by contrast, provides very limited support for terrestrial plants and organisms. This difference has resulted in marked variations between aquatic and terrestrial plants, in terms of their size, reproduction rates, and speciation.

Aquatic organisms can photosynthesise while floating upon, or within, their open-water environments. The dynamic nature of such environments, limits the structural growth potential of these organisms, with the result that they remain small. Furthermore, the lack of any defence against predation puts a premium on high levels of reproduction. Thus, most aquatic plants are single-celled organisms which have a short life-span, but rapid rates of reproduction.

Terrestrial plants need to locate their photosynthesising elements in the manner which will achieve maximum sunlight coverage. This generally predicates a relatively large and complex structure. This implies a slow rate of maturity and reproduction. However, the support structure provides a defence against predation. As a result, the terrestrial plants of the biosphere, have evolved very differently from their aquatic counterparts.

Producers and Consumers

The aquatic and terrestrial photosynthesising organisms initiate the energy interactions of the biosphere, but the bulk of the subsequent interactions involve predation. In ecological terms, the mainstream conventions divide organisms into two main groups, namely: producers and consumers. The interactions take place in ecosystems; while the feeding relationships are classified as food chains, or food webs.

The assemblage of plants and animals. within any given environment, is called a community. In biological terms, a community consists of a variety of species. The term specie, in this context, is generally defined as a group of similar individuals, which actually or potentially are able to breed among themselves. In this context, it should be noted that there are organisms that do not reproduce by a sexual process. These asexual creatures are divided into species, on the basis of their structure.

Variant or subspecies, are those which might be able to interbreed, but which do not do so because they are separated from other similar organisms by geography. In such cases, the classification of species is also by structural variation.

One of the main features of any community is the extraordinary intricacy of the interactions between individuals of the same specie, and of different species. Virtually every specie of plant is eaten by several species of animals. Oak trees, for example, can support hundreds of different species, most of them insects.

Many of the familiar insects are dependent upon flowering plants which are visited for their nectar. This is a symbiotic relationship, as the insects help the plants to fertilise as they transfer the plant pollen, from plant to plant, and place to place.

Green plants are of central importance in all the communities for they are the producers of food upon which most of the other organisms depend. Plants are also the most obvious organisms within a community, often dwarfing the large animals that feed upon them. In addition, there is a huge variety of less conspicuous predators and parasites, feeding on the plant feeders -- and on each other.

When the plants and animals die, their remains are consumed by the decomposers, which include bacteria, fungi, insects and earth worms. These creatures eventually account for everything produced by the plants, so there is no substantial residue of plant material.

Each animal within a community requires food, shelter, and a place to hide from predators. Likewise, plants require light, water and nutrients. In ecological terms, the way in which an individual exploits the environment to satisfy these needs, is called its 'niche'.

It should be noted that an ecological niche combines the actual behaviour of the organism, with the concept of territory. Thus, in the case of most plants and animals, ecological niches usually overlap.

Communities

The essential characteristic of a community is provided by the variety, or diversity, of the species of plants and animals that it contains. No two areas are exactly alike in specie-composition, but there are broad trends which can be defined and measured.

Diversity may be measured by making a list, and estimating the relative abundance of specie that occur within the community. However, because of the complexity of communities, ecologists concentrate upon certain plants, and animals, which are relatively easy to find and identify.

This enables a comparison of specie diversity to be made in different communities; and in different parts of the world; and at various times of the year.

On a world scale, specie diversity increases from the poles to the equator. Moreover, there is a proportional increase, from high altitude to sea level. In addition, there are normally fewer specie on islands -- particularly remote islands, than on continental land masses.

Temperate North America is richer in specie than Western Europe, but such longitudinal differences are much smaller than the latitudinal ones.

In the tropics, the diversity of specie is marked by the scarcity of numbers of individuals within a specie. By contrast, in temperate regions, each specie tends to be relatively common.

Tropical areas also support a great variety of communities, as well as specie. In a country like Uganda, there is almost every conceivable kind of community, varying from low altitude rain forest to high altitude tundra.

In tropical areas, it is typical to find a few common specie, and a great many rare specie. In addition, a common specie in one community may be rare in another apparently similar community.

Inter-specie competition for food, is one of the causes of specie diversity. This competition leads most animals to become either prey, predators, or parasites; or a combination of these variations. Prey/predator relationships lead to a huge range of physiological and behavioural adaptations - which further enlarge specie diversity.

The foregoing paragraphs provide a brief insight into the inter-specie relationships, within the biosphere. However, despite its apparent complexity, the biosphere is still governed by the basic forces of universal evolution.

Note : The Pattern of Change

Thus: atmospheric pressure and gravity, shape the structures of plants and animals. Temperature and humidity affect specie diversity. Surface-to-volume ratios limit growth, and associated reproduction rates. The revolution of the Earth, and its axial tilt create diurnal and seasonal changes, of light and temperature. These seasonal variations affect predation, reproduction, and migration patterns. In addition, the Moon's gravitational variations create the tides, and affect many specie breeding cycles.

These basic, underlying forces are responsible for most of the major changes in biospheric evolution, and speciation. However, most of the evolutionary changes are minor. Indeed, most of them are so small that they only affect organisms in ways that lead to individual variation, rather than speciation.

Evolution of Specie

The final part of this chapter will relate the current mainstream conventions on evolution, supplemented with appropriate examples of mammal reproductive and social behaviour.

Charles Darwin' s theory of evolution has been extensively modified and developed - to match the advances of scientific knowledge. It is now known as the Synthetic Neo-Darwinian Theory of Evolution.

The theory holds that evolution proceeds through natural selection of heritable differences arising at random in each generation. It stresses that evolution through natural selection is opportunistic: in that variations arise by chance, and are selected in accordance with the demands of the environment. Furthermore, it holds that the process takes place steadily.

Variant traits are held to result from mutations, or lasting alterations, that arise at random in individual genes. The theory emphasises the importance of population structure and distribution in the development of new species.

It also incorporates the biological concept of specie (as against the original Darwinian one), namely: that specie are distinguished by their inability to breed with other specie.

Challenges

The emergence of the science of molecular biology, led to two challenges to the Synthetic Theory.

Thus, the Social-biologists claimed that evolution proceeded by molecular determinism, rather than by chance.

By contrast, the proponents of the Neutral Theory suggested that the environment's selective pressures played no role in the eventual genetic variation, within a specie. The Neutral Theory said that chance alone is responsible for the emergence, and long term maintenance, of genetic characteristics.

Finally, some Palaeontologists suggested that evolution occurs on a quantum basis, in fits and starts rather than on a smooth, gradual basis.

This Punctuated Equilibrium Theory suggested that every morphological (structural) change is accompanied by reproductive isolation and speciation. Thus, variant sub-specie are maintained in small populations, which cannot interbreed with the main specie. The small populations allow a rapid rate of evolutionary change to take place -- because the new traits are not diluted within the main specie's gene pool.

The Response

However, most of the research into molecular biology has indicated that genetic variations are the result of chance transformations, combinations, divisions and multiplications.

This research created the impetus for the development for the Neutral Theory, which showed that the number of potential variations, within a population of individuals, was much greater than would be likely to take place on the basis of natural selection.

The supporters of the Synthetic Theory did not dispute this, but pointed out that only variations of an advantageous or disadvantageous nature, would be affected by natural selection.

Thus, it is not the quantity of changes that take place that is important, but the quality of the changes - and the effect this has on the survival of the individual, when its environment is changed in various specific ways.

Likewise, the Synthetic Theory could accommodate the concept of punctuated equilibrium, provided this was not considered a general feature of evolution. It could, and does, exist under certain defined conditions; but where environmental change was gradual, the species change would be equally gradual.

The Social-Biological Theory is less compatible. The concept of the selfish gene, which manipulates the whole organism to achieve some long term evolutionary goal, assumes such a gene must be able to predict the future, in order to know which evolutionary path to take.

No evidence for such predictive ability has been demonstrated by the Social-biologists, and their theory has so far remained outside the mainstream conventions on evolution.
In any event the concept of evolutionary selfishness is well established within the mainstream conventions.

Altruistic behaviour is seen by the Social-biologists as proof of their theory. However, such behaviour can be easily explained by the Synthetic Theory as apparent, rather than real, altruism. Thus, when a bee loses its life by stinging an intruder, its behaviour may be perceived (by humans) to be altruistic, as its death will save the bee colony.

But true altruism only occurs when the individual can perceive the results of a potentially altruistic action. In this context, there is no evidence that bees, or any other similarly behaving organisms, have any perception concerning the results of their actions -- to themselves (or to those the sting).

Most Ethologists see such apparently altruistic behaviour as a simple reaction to stimuli. The fact that such actions saved a bee's colony would mean the survival of the genes which induced this behaviour, on the reasonable assumption that the bee's genes would also exist in other individuals in the colony.

Ethology

Ethologists are concerned with the behavioural interactions and interrelationships of animals. In particular, they research animal behaviour in respect of its causes, development, consequences and evolution.

The great value of Ethology, to students of evolution, is the generalist nature of the discipline. Ethological research has provided a relatively unbiased account of the internal and external stimuli, which play a largely invisible role in the evolution of specie.

As mating and reproduction play a central role in the long term evolution of sexual specie, the following examples may illustrate the value of Ethological Research.

Rats

Thus, a research study of rats, which were mating in multi-male, multi-female groups in a semi-natural environment, showed that the males mounted different females in turn - so that the female with whom the male ejaculated was not the female whom he had mounted earlier in the series.

Each female received intermissions from several males. In this regard, who mounted whom, was determined at least in part, by the females. This was because a female might intercept a male, who was following another female, and induce him to mount her instead.

If two males were present, the dominant male achieved more intromissions before ejaculation, and more ejaculations than the subordinate male.

Similarly, the dominant females were more successful in intercepting males than other females, in order to receive the males' penultimate intromission -- and thus ejaculation.

However, the orderliness with which the dominant and subordinate males alternated their ejaculatory series was particularly noticeable. Each began to mate during the quiescent period, which followed the other's ejaculation.

In this context, it should be noted that other research has shown that intromissions spaced at three minute intervals are most likely to bring a male to the ejaculatory threshold. In females, by contrast, intervals of more than ten minutes are most effective for inducing the progestational state - which a female requires to become pregnant.

These studies show that the multi-intromission/ejaculatory systems, coupled with the timing of the respective male and female states, imply that a social system of mating is desirable for rats - if both dominant males and dominant females are to achieve reproductive success.

In some species, successful reproduction depends upon correct timing with respect to environmental factors and adequate co-ordination with the mate.

Ring Doves

In the case of the Ring Dove: the egg laying, and incubation by the female is stimulated both by the male courtship, and by participation in nest building.

The effect of courtship depends upon both visual and auditory stimuli, and it is important that the male and female should be synchronised through being able to respond to the other's courtship behaviour.

Males likewise become ready for incubation duties -- as a consequence of their participation in courtship and nest building. In both sexes, incubation is maintained by stimuli from both the nest, and the eggs.

The young are fed on pigeons milk, formed by sloughing off the crop epithelium. Crop gland development begins during incubation, but recedes unless stimulation from squabs are received.

The interrelationship of perception and stimuli is illustrated by the female ability to distinguish between unfertilised, and fertilised eggs.

The former are incubated until the normal time of hatching, but then the female starts immediately to recycle; whereas if the eggs are fertile, recycling is delayed for a fortnight.

The difference is also reflected in the increase in plasma luteinizing hormone (a sex hormone) and decreased prolactin during the incubation of infertile eggs. (The decrease in prolactin levels in the blood, eventually stimulates re-ovulation).

Canaries

In a final ethological example: a study of female canaries showed how environmental factors (long day length & male bird song) can act via the hypothalamo-pituitary-gonad system -- by gonadal development, and release of oestrogen.

In this regard, oestrogen has a positive influence on nest building behaviour. As nest building proceeds, stimuli from the nest results in a change of nest materials - from grass on the outside to feathers on the inside. This activity is followed sequentially by a decrease in nest building behaviour, and further reproductive development.

These stimuli from the nest are received through the ventral areas of the skin. The sensitivity of these areas to stimulation from the nest is increased by the development of a brood patch, -- itself under complex hormonal control.

Dominant Females

These ethological examples demonstrate the degree of hormonal development and control, which have evolved in some species. They also indicate the relatively active role played by dominant females, in social species. In this context, although the behaviour of the dominant male may be very obvious, the dominant female may have a greater long term evolutionary influence.

In research into evolution, it is very important to maintain a sense of intellectual balance -- especially if data is subject to possible cultural bias, or interest. In this regard, the Ethological conventions on females sexuality need to be restated.

There are three aspects of female sexuality, namely: attractivity, proceptivity and receptivity.

Female attractivity refers to the female's stimulus value, as inferred from the male's behaviour to her. It includes the full range of stimulation provided by the female, from that which attracts males from a distance, to that which promotes ejaculation, (i.e. , behavioural as well as non-behavioural cues).

In the case of female proceptivity, oestrus females are not only attractive to the male, they are attracted to him. The concept of proceptivity emphasises the importance of female initiative in a mounting sequence.

Female receptivity refers to the consummatory phase of the mating sequence. At a minimum, it includes those responses necessary and sufficient for fertile copulation, including active co-operation in intromission.

These conventions are very important. They should be kept in mind as the final part of this chapter moves from the general to the specific. From animals to mammals. From mammals to primates. From primates to hominoids.

Mammal Mating Systems

But first, a brief introduction into mammal mating systems.

The mating systems of mammals are classified as: Monogamy, Serial Monogamy, Exogamy, Polygamy, Polygyny and Polyandry.

Monogamy is a system in which both males and females mate only with one partner during a breeding season. In Serial Monogamy, the males and females mate with several partners, in a series of monogamous relationships.

Polygamy is a system in which an individual of one sex mates with several members of the opposite sex. When one male mates with several females, the system is called Polygyny; when one female mates with several males, it is called Polyandry.

Exogamy is a system in which the males or females migrate from their home territories, and mate with unrelated members of the opposite sex in another territory.

The mainstream scientific conventions on reproduction consider that the reason for this variety of systems is the variety of ecological niches of the species concerned. In this context, it will be recalled that an ecological niche is a combination of territorial and behavioural concepts. This can be illustrated by examples of the mating systems of various hominoid ape species.

Thus, Orang-utans are generally solitary animals. Each territorial habitat can only support one adult individual. The dominant males do not tolerate any other males in their territory. Likewise the dominant females do not tolerate any other females in their territory, although the female territory will overlap that of the male. As a result the Orang-utan mating system is either monogamy or serial monogamy.

The Chimpanzee mating systems vary with their habitat. The equatorial, Bonobo (Pan paniscus), maintains a small compact territory, which can support a couple of adults and their dependants. This results in a monogamous mating system.

The semi-equatorial, Chimpanzee (Pan troglodytes) occupies a expansive, but marginally productive territory. The dominant male tolerates a dozen or more subordinate males within a territory, though they are invariably close relatives. The females are similarly tolerant, and their territory is either within, or coincident to that of the males. This specie of Chimpanzee has a social system which varies with the productivity of the territory. Their mating systems are similarly variable, comprising a mixture of serial monogamy, polygyny, polyandry, and exogamy.

The Gorillas are more sociable than the Orang-utans, but less sociable than the Chimpanzees. The Gorilla territorial habitat can usually support several adults and their dependants. The dominant males tolerate one or two subordinate males in their territory. Such males are invariably close relations.

The female Gorilla territory is synonymous with that of the males and the dominant female tolerates a small number of subordinate females. The dominant Gorilla male normally mates all the females as they come into oestrous.

However, sometimes the females will be mated by an unrelated mature male, who temporarily joins the Gorilla community, and whose mating activities are tolerated by the dominant male. This is an example of male exogamy.

Hence the Gorilla mating system is either monogamy, series monogamy or polygyny - depending upon the time when the females come into oestrous; and sometimes exogamy.

Social Ecology

To put all this in perspective, the chapter will end with an example of the social ecology of the Chimpanzee specie.

Studies of the Chimpanzee specie Pan troglodytes have shown them to have an unusual social structure. A typical Chimpanzee community consisting of about fifty members occupies a territory from which male Chimpanzees from other territories are excluded. The community members are often on the move within their territory, searching for fruit-bearing trees, and other sources of food.

When fruit is scarce, the community members may split up into smaller foraging parties to seek food on their own. However, when fruit is plentiful the apes prefer to congregate in large groups - to feed, mate, groom themselves, and rest.

This ' fission-fusion' form of organisation is rare among social animals. Even rarer is the female trait of exogamy, i.e. mating outside the home group. When females reach sexual maturity, they emigrate to the territory of a new community to mate. In contrast, the males spend their entire lives in the territory where they were born.

Female exogamy creates a genetic division between the males and females of the community. Thus, while the males are closely related genetically, the females may or may not be related to one another.

Research into the ecology of the Chimpanzee Pan troglodytes schweinfurthii, which inhabits the Kimbale Forest Reserve in Western Uganda, showed that 78% of the Chimpanzees feeding time was spent in consuming fruit, or seeds. They also ate insects and small mammals, including monkeys. In addition, they ate a variety of plant foods, notably: bark, pith, blossoms and young leaves.

In a typical territory, only about 25% of the trees will bear edible fruits. Furthermore, the apes tend to prefer the fruit of relatively rare species of trees, which grow in small clumps scattered throughout the apes' territory.

Like most tropical plants, these trees had no regular fruiting season, and their ripe fruit generally appeared and disappeared within a matter of days.

Monkeys compete with the Chimpanzees, although the former's dependence on fruit is not so great as that of the Chimpanzee. Nevertheless, in the Kimbale Forest, the monkeys outnumbered the chimpanzees by a factor of 4 to 1.

The monkeys are more mobile in the tree canopies, but the Chimpanzees hunt and kill monkeys on the ground. Furthermore, the Chimpanzees can travel more quickly on the ground than the monkeys can travel through the tree canopies.

The research indicated that Chimpanzees are much quicker at identifying edible plants than monkeys, and their greater mobility enables them to search a much wider area for food. Thus, the Chimpanzee's physical and mental abilities make it possible for the individual ape to hold its own against monkeys, and other fruit eaters. The flexibility of the fusion-fission society is also crucial to success in this competition.

Among all the species of wild mammals, only the Chimpanzees display the combination of the fusion-fission society, territoriality and female exogamy. However, this combination is also found in many hunter-gatherer human societies.