Life : Complexity and Diversity

4. Scales of Diversity

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With rare exceptions, each sexually reproduced individual is endowed with a distinctive genetic constitution. Nevertheless living organisms share many genes, the greatest level of sharing characterizing those belonging to the same species. The total number of such species is unknown, but probably exceeds ten million, the vast majority of them being small invertebrate animals.

Diversity within a Species

The diversity of life manifests itself at a variety of levels. At the lowest spatial scale, it may be viewed as diversity of the hereditary material, the molecules of nucleic acid which carry the instructions for conducting much of the business of life. Living organisms reproduce in two different ways: with or without intervention of sexual union. Most higher organisms reproduce sexually, through coming together of egg and sperm cells. The gametes carry only half the hereditary material of the parent after shuffling of parental combinations of genes through genetic recombination. Thus each of the sex cells is different from the other. As a result every individual formed through their union will be unique. Billions of individuals produced through sexual reproduction on earth are in some way different in their hereditary constitution from each other. The extent of variation is a little circumscribed in species that are not products of sexual reproduction. For instance, when a yeast cell splits into two, both cells may carry identical hereditary material; when a curry leaf tree or an Indian cork tree produces new plants from root sprouts, the daughter plants may be identical in their genetic complement to the mother plant. In very special cases,

such as identical twins in our own species, even sexually produced individuals may carry identical hereditary material. But these are rare exceptions.

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Almost every sexually produced individual is different from every other in some detail of its hereditary material. But two such individuals may also be similar in many ways. Indeed a mother and a daughter at a minimum share half their hereditary material. If the husband and wife shared some traits, as they often would, then the mother and daughter would share much more than half of the hereditary material. Sets of individuals would share more genetic material with other members of the set such as for instance, all human beings, or all bonnet macaques, or all domesticated donkeys, or all banyan trees. Having much in common, such individuals are potentially capable of reproducing with members of the opposite sex within the set. These constitute what biologists call species. Generally, members of a species are interfertile and may breed with each other under natural conditions. So all humans constitute one species, all tigers another, all lions a third. Although lions and tigers may interbreed in zoos, they never do so in nature, and therefore deserve to be considered as separate species. On the other hand, white Europeans, black Africans, mongoloid Orientals, Australian aborigines, are all perfectly interfertile and are clearly members of the same human species (Figure 1). Diversity of life is therefore best viewed in two major contexts: diversity of hereditary material amongst members of the same species, and the diversity of species within a biological community, or in any specific region such as the Indian subcontinent.

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The recent knowledge of the primary sequence of hereditary material has brought in a great deal of information on the extent of variation amongst members of the same species. The hereditary material of any individual is made up of several thousand to several hundred thousand units or genes. There

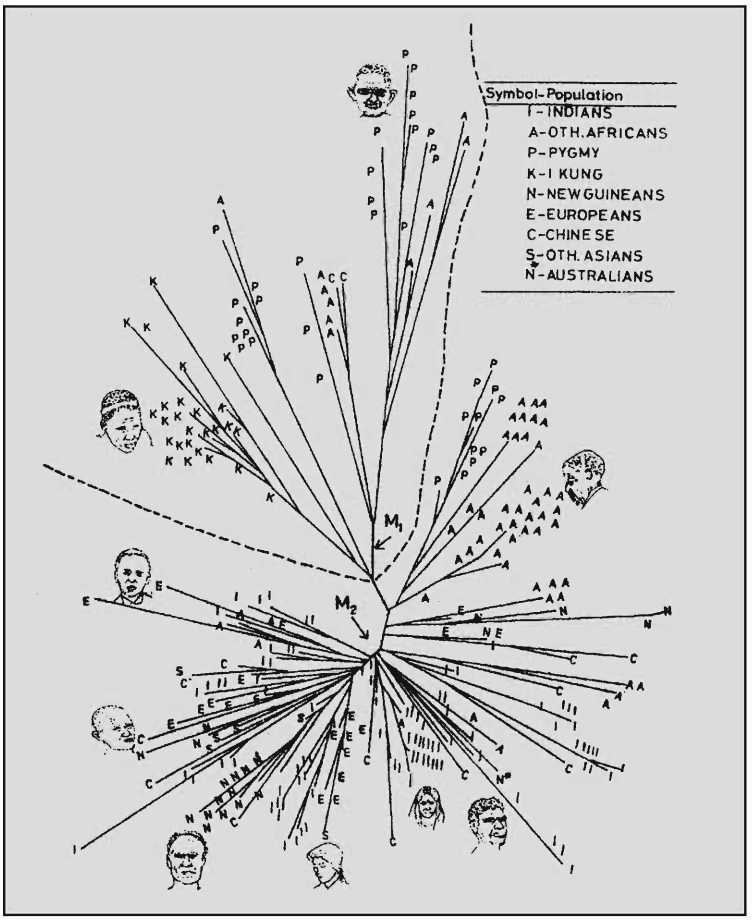

Figure 1 A tree depicting genetic relationships amongst modern humans. This tree is based on 745 nucleotide base sequences of 293 individuals from a highly variable region of mitochondrial DNA. While Africans and non-Africans tend to cluster separately, Europeans, Asians and Australian aborigines are intermingled (based on J L Mountain, J M Hebert, S Bhattacharyya, P A Underhill, C Ottolenghi, M Gadgil, and Cavalli-Sforza. Demographic history of India and mtDNA – sequence diversity Am. J. Hum. Genet., 56:979-992. 1995).

is little variation for 60% to 80% of these genes; they are believed to be identical in all members of a given species. Several forms occur at the remaining 20% to 40% of the genes. Every individual in a sexually reproducing species carries two sets of genes, one derived from the mother, the other from the father. Between 5% and 14% of these two sets of genes are in more than one form; for instance the mother having contributed a gene for brown and the father for black eyes. This diversity within species is of great significance as the raw material for evolutionary change. For instance, mosquitoes in many parts of India are no longer killed by DDT. This is because the mosquito species contained some individuals with genes that permitted the bearers to withstand exposure to DDT.

Sexually reproducing organisms are polymorphic at 20% to 40% of genetic loci.

Before DDT came into vogue there were very few individuals carrying such genes. But once DDT began to be sprayed on a large scale such individuals were at a great advantage. They survived while mosquitoes bearing genes that rendered them susceptible to DDT were killed. So gradually the proportion of mosquitoes with genes conferring DDT resistance has increased till most Indian mosquitoes today are DDT resistant. The tremendous diversification of life from a single origin three and a half billion years ago till today is ultimately based on such evolutionary change for which genetic variation within species has provided the basic raw material.

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So much for variation within a species. Higher levels of differences in the hereditary material mark one species from another. Where they are closely related, as in the case of humans and chimpanzees, much of the hereditary material is held in common. Thus humans and chimps have about 98.4% of the same genes, although the exact form of the genes would differ for a much larger proportion. We share about 97.7% of the genes with gorillas, 96.4% with Orangutans, and 93% with other old world monkeys (*Figure 2*). But even very different organisms such as green plants and mammals have a proportion of widely

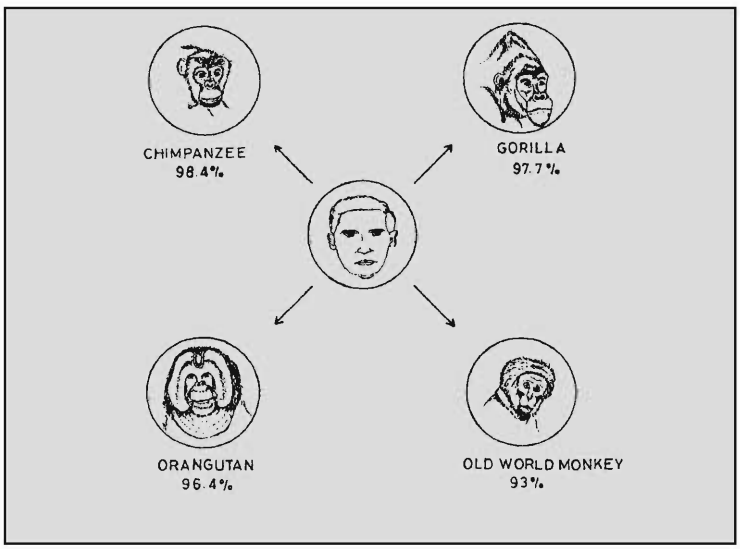

Figure 2 While there may be considerable variation amongst allelic forms of given genes even amongst members of a given species, related species have much of their genetic material in common. This figure depicts this relationship amongst the human species, other apes and old world monkeys.

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shared genes -- for instance the gene coding for the production of a protein called Histone H4 involved in binding nucleic acids. This protein differs in only 2 out of 100 amino acids in organisms as different as the pea plant and cattle.

Diversity Across Species

The most striking aspect of diversity around us is that of different kinds of species of living organisms. The viruses that we cannot see, but that we broadcast with every sneeze; the bacteria that we cannot see, but drink with every glass of buttermilk, the mold that grows on rotting fruit, the mushrooms that grow on rotting logs of wood, the banyan trees that line our avenues, the fig wasps that live inside the fruit of banyan trees, the crimson breasted barbets and the koels that feed on these fruit. How many such different species of living organisms are there any way? What we know for sure is that about a million and a half have been described in scientific literature to this date. A quarter of a million of these are plants, over a million insects and spiders. Only 4000 different species of bacteria and 5000 of viruses have been described. There are 45000 species of vertebrates described – fish, frogs, snakes, turtles, birds, mammals all put together. There are almost an equal number, 40000 species of crabs, shrimps and related crustacean animals described.

But every day new species are being discovered and described. Many of these are small insects and mites a few millimeters in size living in the canopy of tropical forests. It is speculated that there may be as many as ten to fifty million species of such animals still unknown to science. Most of the vertebrates have probably already been described, and perhaps only another 5000 or so remain to be added to the known list of 45000. So one can only speculate on the total number of species of living organisms on the surface of the earth today. Very likely it is around 15 million, ten times the number of species described. But it could be as many as 100 million.

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Suggested Reading

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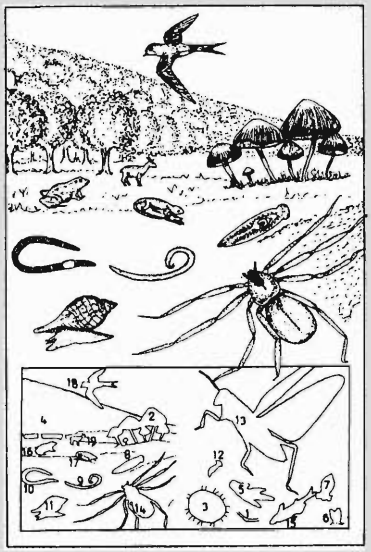
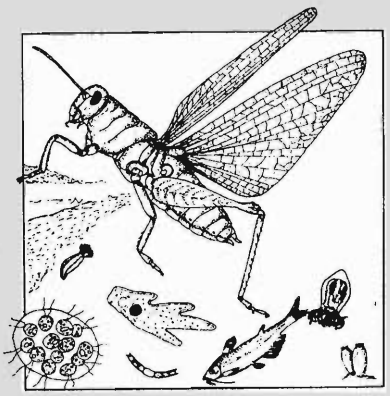
V H Heywood. Global Biodiversity Assessment. Published for the United Nations Environment Programme. Cambridge University Press, Cambridge, pp. 1140. (1995)





A Species Scape

There is a tremendous variation in the number of species belonging to different groups of organisms; this variation is indicated by the relative sizes of different organisms. Thus there are many more species of insects and crabs and their relatives. Consequently these loom much larger in the species scape than do fishes or frogs. The code and number of species described so far from the various groups are given below. This list omits viruses and some minor groups of invertebrates.

1 Monera (bacteria, cyanobacteria), 4800
2 Fungi, 69,000
3 Algae, 26,900
4 Higher plants, 248,400
5 Protozoa, 30,800
6 Porifera (sponges), 5000
7 Cnidaria and Ctenophora (corals, jellyfish, comb jellies and relatives), 9000
8 Platyhelminthes (flatworms), 12,200
9 Nematoda (roundworms), 12,000
10 Annelida (earthworms and relatives), 12,000
11 Mollusca (mollusks), 50,000
12 Echinodermata (starfish and relatives) 6,100
13 Insecta, 751,000
14 Non-insectan arthropods (crustaceans, spiders etc) 123,400
15 Fishes and lower chordates, 18,800
16 Amphibians, 4,200
17 Reptiles, 6,300
18 Birds, 9,000
19 Mammals, 4000