Molecular Evidence of Evolution

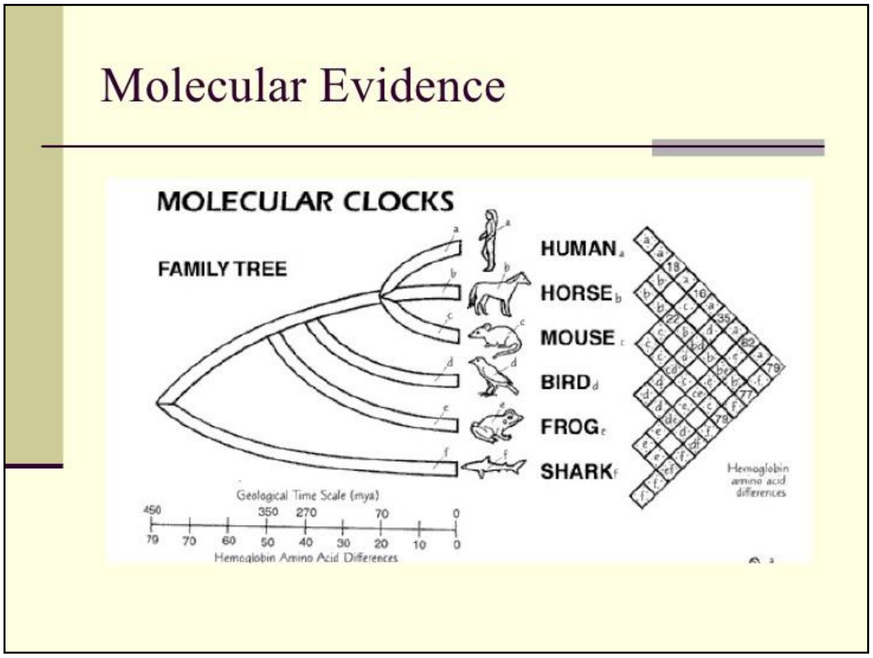
Like anatomical structures, the structures of the molecules of life reflect descent with modification. Evidence of a common ancestor for all of life is reflected in the universality of DNA as the genetic material and in the near universality of the genetic code and the machinery of DNA replication and expression. Fundamental divisions in life between the three domains are reflected in major structural differences in otherwise conservative structures such as the components of ribosome and the structures of membranes. In general, the relatedness of groups of organisms is reflected in the similarity of their DNA sequences—exactly the pattern that would be expected from descent and diversification from a common ancestor.

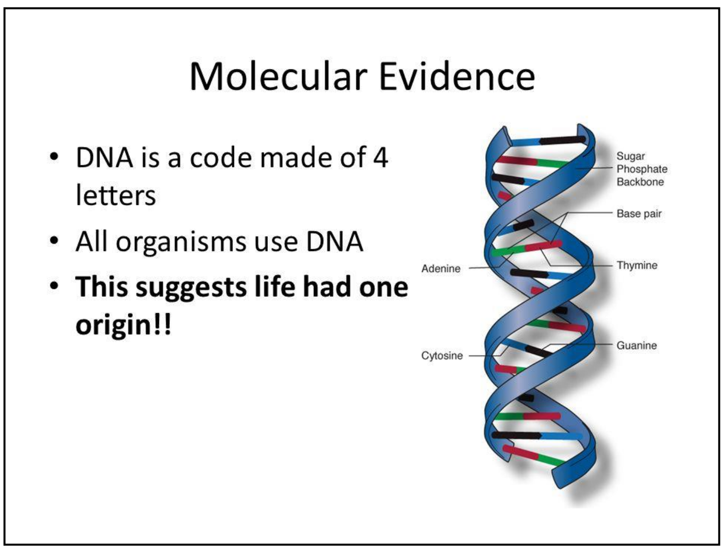
DNA sequences have also shed light on some of the mechanisms of evolution. For example, it is clear that the evolution of new functions for proteins commonly occurs after gene duplication events that allow the free modification of one copy by mutation, selection, or drift (changes in a population's gene pool resulting from chance), while the other copy continues to produce a functional protein.

Beginning in the 1940s, scientists studying molecules and DNA have confirmed conclusions about evolution drawn from other forms of evidence. **Molecular clocks** are used to determine how closely two species are related by calculating the number of differences between the species' DNA sequences or amino acid sequences. These clocks are sometimes called gene clocks or evolutionary clocks. The fewer the differences, the less time since the species split from each other and began to evolve into different species.

A chicken and a gorilla will have more differences between their DNA and amino acid sequences than a gorilla and an orangutan. That means the chicken and gorilla had a common ancestor a very long time ago, while the gorilla and orangutan shared a more recent common ancestor. This provides additional evidence that the gorilla and orangutan are more closely related than the gorilla and the chicken. Which pair of organisms would have more molecular differences, a mammal and a bird, a mammal and a frog, or a mammal and a fish?

On the other hand, animals may look similar but can have very different DNA sequences and evolutionary ancestry. Which would have more DNA sequences in common, a whale and a horse, or a whale and a shark?



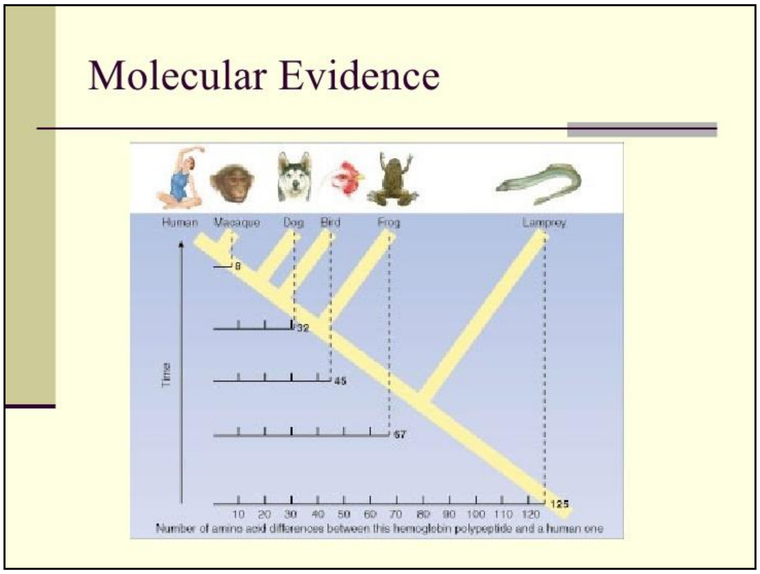


The **genomes**, or all the DNA sequences of all the genes of an organism, have been determined for many different organisms. The comparison of genomes provides new information about the relationships among species and how evolution occurs.

Molecular evidence for evolution also includes:

1. The same biochemical building blocks, such as amino acids and nucleotides, are found in all organisms, from bacteria to plants and animals. Recall that amino acids are the building blocks of proteins, and nucleotides are the building blocks of DNA and RNA.

2. DNA and RNA determine the development of all organisms.
3. The similarities and differences between the genomes confirm patterns of evolution.



Globins: Globins are small heme-proteins with a characteristic three-on-three α-helical sandwich structure. They have the ability to bind oxygen and other gaseous ligands between the iron ion of the porphyrin ring and—typically—a histidine of the polypeptide chain. Globin-type proteins are widespread and occur in archaea, bacteria, plants, fungi, and animals and exhibit an enormous structural and functional diversity. Although globins are famous for their capability to transport and store oxygen, thus, sustaining oxidative metabolism in the cell, in recent years, other functions have been discovered.

In 1959, scientists at Cambridge University in the United Kingdom determined the three-dimensional structures of two proteins that are found in almost every multicelled animal: hemoglobin and myoglobin. Hemoglobin is the protein that carries oxygen in the blood. Myoglobin receives oxygen from hemoglobin and stores it in the tissues until needed. These were the first three-dimensional protein structures to be solved, and they yielded some key insights. Myoglobin has a single chain of 153 amino acids wrapped around a group of iron and other atoms (called "heme") to which oxygen binds. Hemoglobin, in contrast, is made of up four chains: two identical chains consisting of 141 amino acids, and two other identical chains consisting of 146 amino acids. However, each chain has a heme exactly like that of myoglobin, and each of the four chains in the hemoglobin molecule is folded exactly like myoglobin. It was immediately obvious in 1959 that the two molecules are very closely related.

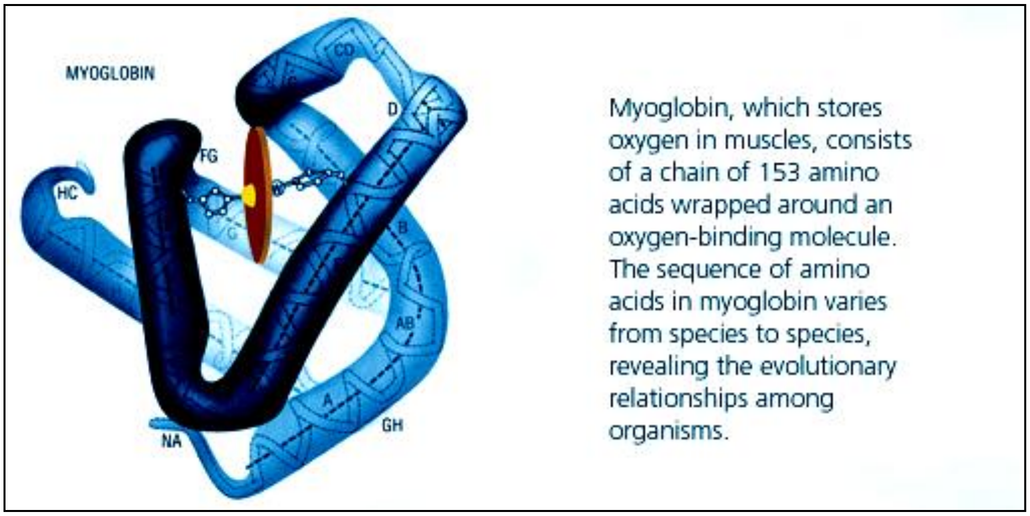


Fig: Myoglobin

Comparative Sequences: During the next two decades, myoglobin and hemoglobin sequences were determined for dozens of mammals, birds, reptiles, amphibians, fish, worms, and molluscs. All of these sequences were so obviously related that they could be compared with confidence with the three-dimensional structures of two selected standards--whale myoglobin and horse hemoglobin. Even more significantly, the differences between sequences from different organisms could be used to construct a family tree of hemoglobin and myoglobin variation among organisms. This tree agreed completely with observations derived from paleontology and anatomy about the common descent of the corresponding organisms.

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