

# FROM JAWBONES TO GENOMES

## THE HISTORY OF A SCIENCE

by Scott Rifkin

*How does one study really ancient history? Creative scientists have used a diverse array of technical and conceptual approaches to try to glimpse the dawn of humankind. In this essay, a student looks back on the past and into the future of his chosen discipline, evolutionary biology.*

In 1925, the same year that John Scopes stood trial in Tennessee for teaching evolution in public schools, Australian anatomist Raymond Dart described a skull found in the Taung lime quarry near Johannesburg, South Africa. The skull was small, a juvenile's, with an ape-like face. But a cast of the inside of the skull suggested an unexpectedly human-like brain. Dart saw evidence of brain structures that apes do not possess but that could have represented a step toward similar structures in modern human brains. He excitedly rushed a manuscript to the journal *Nature*, announcing the discovery of *Australopithecus africanus*, one of the first "missing links" between humans and apes ever to be found.

Dart is one of many explorers who have used scientific approaches to try to reconstruct our most ancient past. Evolutionary biology has been built by such individuals—astute enough to see suggestive details or trends in often very fragmentary data, and bold enough to go public with their speculations.

### ORIGINS OF A SCIENCE

Evolutionary biology is a synthetic discipline, encompassing a number of subfields with a common focus on the history of life. It was born as a modern science in the mid-1800s amidst a growing awareness that living forms change not only over a lifetime—development—but also over longer stretches of time—evolution. The refinement of sophisticated techniques for comparing the bones and body parts of animals accelerated the accumulation of evidence of such change.

In 1859, Charles Darwin shook the world with the publication of *On the Origin of Species*, in which he laid out a framework for understanding the history of life. His theory of natural selection rests upon the fact that members of a population vary, and part of that variation is heritable. Different parents have different numbers of offspring, each of which possesses a unique set of characteristics.

Darwin realized that, since not all offspring will survive to reproduce, only some heritable traits will be passed to the next generation. Small changes will accumulate over many generations until descendants look quite different from their ancestors. By framing evolution in these terms, Darwin proposed a theoretical model for understanding why populations change over time.

Another idea that shaped evolutionary biology developed concurrently, not in the bustling intellectual community in which Darwin's

ideas were hotly debated but in a secluded Moravian monastery. There, Gregor Mendel worked out the basic principles of genetic inheritance by breeding and studying generations of pea plants. Not until decades after his death did Mendel's discoveries become a pillar of modern biology.

Thus, Darwin developed his theory of natural selection entirely without the benefit of the concept of genes. Only in the 1920s did evolutionary biology finally emerge as a coherent discipline, melding Darwin's and Mendel's ideas into a larger framework that incorporated comparative anatomy, paleontology, natural history, and genetics.

### ANATOMY LESSONS

Throughout most of evolutionary biology's history, the main evidence for evolution has come from comparative studies of living organisms, like Darwin's studies of birds, and from similar analyses of the fossil record. Comparative anatomists and paleontologists became ingenious at inferring characteristics about organisms from their anatomical structure.

An animal's gait, for example, is governed by such features as the relative lengths of its upper and lower limbs, the shape of its pelvis, and the points where its muscles attach to its leg bones. Its running speed and power can be estimated using the principles of mechanics. Using these and other anatomical data (e.g., of structures of the jaw and teeth), one can speculate about how and what an animal ate, what role it may have played in the food chain, even how the species' social system worked. (This process was engagingly dramatized in *Jurassic Park* when a paleontologist described the probable lifestyles of various dinosaurs on the basis of skeletal remains.)

However, there is sometimes a fine line between well-informed and fanciful hypothesizing. A famous misinterpretation was made in 1961 when paleontologist Elwyn Simons "reconstructed" an early primate on the basis of a single broken upper jawbone. Proposing that 15-million-year-old *Ramapithecus* represented the first hominid, Simons constructed a whole life history for the primate, claiming it was bipedal, made tools, was social, and hunted. For fifteen years he continued to develop his theory, incorporating favorable new evidence and rebuffing challenges. Finally, newer data invalidated his hypothesis. *Ramapithecus* is now thought to be an early relative of the orangutan.

### THE STORIES GENES TELL

Genes are the biological molecules that mediate heredity and therefore natural selection. With the development of methods to analyze genes and DNA, genetics has become the dominant science underlying evolutionary biology and the technique of choice for addressing many evolutionary questions. Why? Because while genetic techniques have their limitations, on balance they are more objective than fossil analysis, with less chance of contamination by preconception, expectation—or wishful thinking.



"Taung child" skull. From *THE FOSSIL TRAIL*  
by Ian Tattersall.

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Molecular techniques can be used to measure genetic variation among populations. A population's genetic profile undergoes a slow change over time, due both to random mutations—a phenomenon called genetic drift—and to natural selection. When subgroups of an initially homogeneous population migrate apart, their genetic profiles tend to change differently, to drift apart. The genetic difference, or *genetic distance*, between two populations thus gives an indication of how recently the two were one. Complex computer models use genetic distances to construct family trees that show how closely different populations are related.

One of the most famous results using molecular techniques was the unraveling of the relationships between the great apes: orangutans, gorillas, common and pygmy chimpanzees, and humans. Before genes were used to construct family trees, anatomical studies suggested that chimpanzees and gorillas were very closely related, and it wasn't clear where humans fit in. However, much to everyone's surprise, molecular data has unequivocally shown that, in the great apes' family tree, the orangutan branch split off first, then the gorilla branch, and only much later did the chimpanzee branch split off from the line that has led to humans. Scientists are now studying genetic distances between more closely related species like the West African and East African common chimpanzees.

Like any tool, genetic analysis has its own potential for mishap. This young branch of evolutionary biology has had its share of controversies and embarrassments—due not to the genetic data itself, but to flaws in the complex computer programs used to analyze the data and generate family trees. Scientists are now more cautious about double checking computer-generated results before publishing them.

## FUTURE DEVELOPMENTS

Today, evolutionary biology is even more of a composite discipline than ever, strengthened by the many different intellectual strands within it. While it continues to draw heavily upon the subfields like comparative anatomy and paleoanthropology that contributed so much to its early growth, evolutionary biology has been energized by a host of new arrivals: molecular biology, computer modeling, complexity theory. Like the subjects it studies, the field keeps evolving.

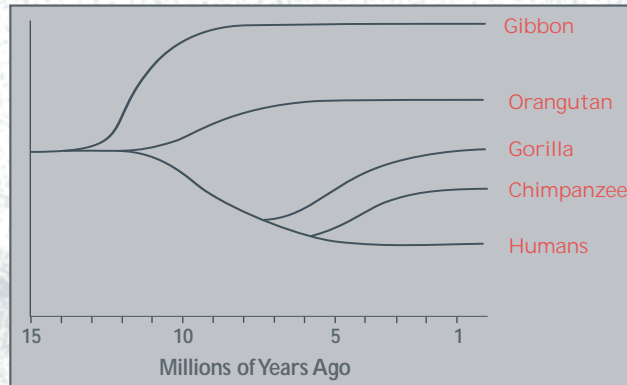
Although Darwin's theory of natural selection has been a powerful tool in addressing *why* questions, it is silent when it comes to the intriguing *how* questions: How does evolutionary change actually take place at the molecular level? How does a mutation in a strand of DNA change the number of vertebrae of a hominid, perhaps allowing it to walk upright more easily?

Until recently, many of the most interesting questions were too difficult to be studied. But an avalanche of discoveries in genetics has made molecular evolutionary biology one of the hottest and most promising areas of science today (a little unabashed advocacy for my own field of interest!)—one that *does* address those *how* questions. In the foreseeable future, we should be able to understand how changes in DNA

sequences relate to changes in anatomy, and perhaps even how ecological change drives the whole process.

As Theodosius Dobzhansky, one of this century's most influential scientists, said, "Nothing in biology makes sense except in light of evolution." ■

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*Hominoid family tree. Adapted from R.S. Corruccini and R.L. Ciochon (Eds.), (1994), INTEGRATIVE PATHS TO THE PAST, Prentice-Hall, Inc.*



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