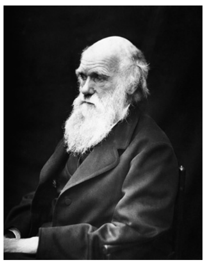
CHAPTER 1

Introduction to Evolutionary Anthropology



GOALS

By the end of this chapter you should understand:

1. Research topics explored by evolutionary anthropologists.
2. Basics of the scientific method.
3. Historical development of evolutionary concepts.
4. Charles Darwin and the theory of natural selection.
5. Gregor Mendel's studies of trait inheritance.

CHAPTER OUTLINE

What Do Evolutionary Anthropologists Study?

How Do Evolutionary Anthropologists Conduct Their Research?

Development of Evolutionary Concepts

Introduction

I remember my first course in anthropology. Because my initial request for a course on biological evolution was denied due to enrolment limits, a friend suggested I take a popular course focusing on what he called "monkey stuff." Sounded interesting, I thought, so I enrolled in Introduction to Biological Anthropology. Being a newcomer to campus, I got lost and was late for the first class. As I hurried toward the classroom, I heard strange animal-like noises echoing off the lockers in the hallway. The noises got louder as I approached my designated room. I stepped into the classroom to discover the professor hooting like a wild monkey! As I negotiated through the seats already occupied by my fellow students, the professor told us about the course. In the weeks ahead, we would learn about the mechanisms of biological evolution, the ecology and behaviour of our closest biological relatives, and the anatomical trends in our biological evolution. In our studies, we sought to answer the question, what is it to be human? I knew by the end of the course that I wanted to be an anthropologist!

What's the first thing that comes to your mind when you hear the word *anthropology*? Perhaps you picture researchers studying primitive human cultures deep in the jungle, archaeologists struggling to locate treasures in the ruins of ancient cities, or scientists digging for fossils under the blazing sun in Africa. Certainly, some aspects of all these activities relate to **anthropology.** Anthropology is a **holistic** science comprising the following five disciplines: socio-cultural anthropology, linguistic and semiotic anthropology, archaeology, medical anthropology, and biological anthropology. Socio-cultural anthropology is the comparative study of human cultures and societies. Linguistic and semiotic anthropology focuses on how language and other systems of human communication contribute to the reproduction, transmission, and transformation of culture. Archaeology is the scientific study of the material evidence of human activities in the past. Medical anthropology focuses on human health and its relationship with culture, behaviour, and biology. Biological anthropology is the study of human and **non-human primates** in their biological and demographic dimensions. Evolutionary anthropology, a specialized subdiscipline within biological anthropology, is the application of modern evolutionary theory to studies of the **morphology**, **ecology,** and behaviour of human and non-human primates. This book employs an evolutionary perspective on humans and non-human primates. Why? Because as a famous evolutionary biologist stated, "Nothing in biology makes sense except in the light of evolution" (Dobzhansky, 1973).

Anthropology ■ The global and holistic study of human culture and biology.

Holistic ■ Considering all aspects of the research subject.

Non-human primate ■ Any primate that is not a human.

Morphology ■ The study of the form and structure of organisms.

Ecology ■ The study of interrelationships of organisms and their environment.

Biological evolution and other associated processes influence every aspect of our lives (Groen et al., 1990). Do you like good food and drink? Our ability to taste, smell, and in some cases detoxify food results from evolutionary processes. Do you like looking at artwork or participating in sports? Our ability to see in colour and judge distance is the result of millions of years of natural selection. Do you like scary movies? If so, then perhaps you have noticed that watching a scary movie often makes the hairs stand up on your arms and the back of your neck. This uncontrolled response is similar to what happens to frightened cats: they fluff up. A tiny muscle, the arrector pilorum, can raise each hair on the human body. The body's response to being scared is to revert to an ancient mammalian trick of looking bigger and more imposing to some perceived external threat! As you will learn in the upcoming chapters, biological evolution has influenced and continues to influence humans, as it has all other life forms on Earth.

Evolutionary concepts are hidden in some of the most popular movies, television shows, and advertisements. For example, the computer-animated movie *Finding Nemo* is the story of a clownfish (*Amphiprion ocellaris*), named Marlin, who loses his wife and all but one of their offspring to a predator. The remainder of the movie describes Marlin's heroic efforts to find and save his son Nemo from captivity. However, clownfish biology is different from that portrayed in the movie: The death of the resident breeding female, such as Nemo's mom, results in one of the local males, like Marlin, changing sex to become the new breeding female. Yes, you read that correctly: Marlin should have become Marlina!

Speaking of cartoons, you will see a number of editorial cartoons used in this text to help you understand the humorous side of common misconceptions about biological evolution (starting with

Figure 1.1). This chapter will introduce you to the exciting science of evolutionary anthropology.

What Do Evolutionary Anthropologists Study?

Evolutionary anthropologists and biologists seek answers to intriguing questions of where we come from, who we are, and why we are here (Futuyma, 1998). Evolutionary anthropologists specialize in primatology, paleoanthropology, human variation, medical anthropology, and forensic anthropology. Following the cartoon is a brief introduction to these five research disciplines.

Figure 1.1

Introducing three characters—Cucu, Bento, and Geo—who at various points in the book provide a comical view of common misconceptions people have about evolutionary concepts.

Primatology

Primatology is the scientific study of our closest **extant** biological relatives: non-human primate species. For now, we can define *species* as a single, distinct class of living creature with features that distinguish it from other living creatures. You can find a more detailed explanation of species concepts in Chapter 2. Primatologists conduct their research on a variety of **primate** species and research topics, ranging from descriptions of primate anatomy through field studies of wild animals to investigations of primate psychology. Primatologists are at the forefront of research efforts to conserve primates in vanishing tropical ecosystems. For example, Dr. Colin Chapman and his research team at McGill University have spent decades studying how primates respond to deforestation in Africa (Chapman et al., 2000, 2005). Their groundbreaking work indicates that even 15 to 25 years after logging, the abundance of some primate species have still not returned to levels recorded before logging occurred. They have linked this slow recovery to a fascinating pattern of temporal and spatial variations in parasites and the quality and abundance of food resources.

Extant ■ Living representatives of a species exist.

Primate ■ Any extant or extinct member of the order of mammals that includes lemurs, tarsiers, monkeys, apes, and humans.

Paleoanthropology

Paleoanthropology is the multidisciplinary study of the biological evolution of humans and non-human primates. Although paleoanthropologists are perhaps best known for excavating **fossils,** many researchers also investigate the advent of and changes in human cultural activities, including tool use, subsistence patterns, and disease. We know that the primate fossil record stretches back as far as 50 to 60 millions years (Fleagle, 1999). Ancient primates evolved and went **extinct** in response to a variety of geological and biological processes. Paleoanthropologists also investigate the evolutionary history of behaviour in human and non-human primates. For example, Dr. Mark Collard of Simon Fraser University combines biological evolution and archaeology to understand patterns of primate and human evolution (Collard and Wood, 2000; Lycett et al., 2007). Dr. Collard has suggested that the behavioural patterns of some primates result from social learning, and that these creatures share with humans the unique distinction of having culture.

Fossils ■ Organic remains that have been transformed by geological processes into a mineralized form.

Extinct ■ No living representative of a species exists.

Human Variation

Anthropologists study human variation to determine spatial and temporal variations in human features (Jobling et al., 2004). Observe your fellow humans the next time you are on campus or at another major urban centre, such as an international airport. You're likely to see that we come in an impressive array of sizes, shapes, and colours. We also have considerable skeletal and dental variations, which are, of course, much harder to see. Despite this variation, all humans are members of one species, which evolutionary anthropologists refer to as *Homo sapiens.* For example, Dr. Esteban Parra at the University of Toronto-Mississauga uses genetic markers to answer questions related to the biological evolution of skin pigmentation in human populations (Parra et al., 2001; Shriver et al., 2003). This research indicates that human skin pigmentation has been subject to strong selection pressures due to environmental factors rather than population history.

Medical Anthropology

Medical anthropology, the study of how social, environmental, and biological factors influence health and illness of individuals at the community, regional, national, and global levels, is a recent addition to evolutionary anthropology. Many medical anthropologists investigate spatial and temporal variations in human survival, disease, and health disparity. Dr. Robert Hoppa, of the University of Manitoba, investigates the relationships between health, culture and biology, and the interactions between environment, health, and behaviour in ancient human populations (Green et al., 2003; Hoppa, 2000). Dr. Hoppa and his research team are conducting groundbreaking studies of the skeletons of the indigenous peoples of Canada to reconstruct their cultural history at both the individual and population levels.

Forensic Anthropology

Forensic stuff fascinates many people! If you watch television, then you are likely aware of popular programs, like *Bones* and the *CSI* series, that deal with forensic scientists and their work on homicide investigations. There are equally popular books dealing with forensic science, such as Patricia Cornwell's series on the fictional character Dr. Kay Scarpetta. While forensic science encompasses a variety of biological fields of research, such as genetics and toxicology, forensic anthropology focuses only on the skeletal remains of humans. By analyzing these remains, forensic anthropologists seek to determine the age, sex, stature, ancestry, and any trauma or disease of the deceased. For example, Dr. Mark F. Skinner from Simon Fraser University has consulted on hundreds of forensic cases in Canada (Bell et al., 1996; Skinner, 1987). Dr. Skinner has also investigated allegations of mass graves in Afghanistan, Bosnia, Serbia, and East Timor.

How Do Evolutionary Anthropologists Conduct Their Research?

Evolutionary anthropologists conduct three types of research: descriptive, causal, and applied (Bryman, 2001). Descriptive research involves collecting data about the study subjects or objects. If, for example, I were to walk through a forest recently damaged by logging and notice that some primate species were missing, I would be conducting descriptive research. However, although my observations are of conservation interest, they do not provide a means to determine what caused the primates to disappear. They could be gone because of hunting pressures, loss of critical food resources, sensitivity to habitat disturbance, or any number of other factors. Therefore, you can see that descriptive research does not demonstrate causal relationships. Causal research involves looking for one thing that causes another thing to happen or change. Returning to my previous example, I could look for a cause-and-effect relationship between ecological factors, such as the distribution and density of critical food resources and the loss of primate species in the logged forest.

Medical and forensic anthropologists tend to focus on applied research. In applied research, a scientist determines the means by which a specific, recognized need can be met (Miller and Salkind, 2002). Applied research can also be used in the previous example of deforestation effects on local primates. If one of my variables, such as the distribution of food resources, was a strong predictor of primate diversity, then applied research could involve planting various primate food trees in the remaining forest. In this way, I could determine whether the addition of specific food trees increased primate diversity. These research paradigms are directly relevant to formulating and testing scientific theory.

What's a Theory?

A scientific theory is a well-substantiated explanation of some aspect of the natural world that incorporates facts, laws, predictions, and tested hypotheses. A scientific theory is very different from a **common theory.** For example, I have a common theory that I always pick the slowest lineup to pay for items at a grocery store. Presumably, I have sufficient data to support my theory because I have been to grocery stores hundreds of times. Is my common theory supported by enough data to form a scientific theory? No! I need to set up a series of experiments to test the hypothesis that I consistently have longer wait times than other patrons in grocery stores. In this experiment, I would need to control for interpersonal differences in grocery quantities, unloading times from carts, cashier speed, payment methods, and so on. As you can see, things get rather detailed when someone conducts hypothesis testing in science. Therefore, unlike a common theory, a scientific theory is a widely accepted set of ideas that produce hypotheses that can be tested and refined by the scientific community.

Common theory ■ An idea based only on conjecture or personal opinion.

What's a Hypothesis?

A hypothesis is a testable statement about the natural world that a researcher uses to build **inferences** and explanations. Before conducting an experiment, a scientist evaluates and defines specific aspects of each hypothesis. From there, a scientist ensures that each hypothesis is **falsifiable.** Wait a second! You may be thinking that scientists are supposed to prove, not disprove, their hypotheses. This is not the case. A simple example can illustrate the critical importance of falsifiable hypotheses. Hypothetically, someone could suggest that giant, sentient cucumbers from an alternate universe brought the first life forms to Earth and other plants in our galaxy. The research should not proceed because, in part, the hypothesis is not falsifiable—there is no way to test whether this is or is not the case. Specifically, you cannot falsify the existence of an alternative universe in evolutionary anthropology, and there are no existing data to support the existence of giant, sentient cucumbers capable of interstellar travel. Thus, a hypothesis is not an "educated guess." A scientist uses observations from previous research to formulate and then test a hypothesis. For example, each year I teach a large course on introduction to anthropology. I also advise students on their study habits. Based on my observations, I could hypothesize as follows: If student grades in class are related to studying time, then people who study for longer time periods will have a higher final grade. An alternative hypothesis could be this: If student grades in class are related to studying quality, then people who have better study periods will have a higher final grade. Each hypothesis is falsifiable because I can collect data on the study habits of the students and their final grades. I could also set up some experiments to test my hypotheses using the scientific method.

Inference ■ A process of reasoning in which a conclusion is derived from one or more facts.

Falsifiable ■ A study design that enables the researcher to make observations that disprove a hypothesis.

The Scientific Method

Evolutionary anthropologists employ the scientific method as often as possible in their research. The scientific method involves investigating phenomena, acquiring new knowledge, or correcting and integrating previous knowledge (Cohen and Nagel, 1934). The scientific method generally involves five sequential processes: (1) observation of the phenomena, (2) formulation of a hypothesis concerning the phenomena, (3) development of methods to test the validity of the hypothesis, (4) experimentation, and (5) a conclusion that supports or modifies the hypothesis. Data collected by a scientist must be repeatable, observable, empirical, and measurable. The scientific method involves collecting **quantitative data,** which is information sometimes referred to as "hard" or numerical in nature, and **qualitative data,** which is information on just about anything that is non-numerical in nature. For example, a medical anthropologist can interview study subjects suffering from various parasitic illnesses. Because there is no direct, empirical means of measuring discomfort, the researcher may collect qualitative data on pain levels (by asking people to evaluate it as low, moderate, or extreme). Conversely, the researcher could collect quantitative data on the number and kinds of parasites found in the blood and fecal samples of the local people.

Quantitative data ■ Information measurable or quantifiable on a numeric scale, such as body mass or the number of primate species in a protected area.

Qualitative data ■ Information based on observations that cannot be reduced to numerical expression.

Development of Evolutionary Concepts

Note to Formatter: Pls check font of the glossary definitions—ensure consistency.

Before we get into modern evolutionary theory, it's important to have a short, historical review of the people that influenced the development of evolutionary concepts. Historians trace ideas on biological evolution back as far as 2600 years ago in ancient Greece and Asia, to the works of Aristotle and Zhuangzi. For example, Aristotle's observations of the anatomy of various aquatic mammals and fish were thousands of years ahead of their time. Almost 2400 years ago, Zhuangzi suggested that living things have the power to transform themselves to adapt to their surroundings. In 18th-century Europe, a series of monumental changes occurred in scientific explorations and discoveries related to biological evolution.

Historical Contributors

Carl Linnaeus (1707–1778) was a Swedish physician and **botanist,** with a strong interest in **classifying** plants and animals (Figure 1.2). Often referred to as "the father of modern **taxonomy**," Linnaeus began his work with forays into local gardens, expanded into remote areas of Sweden, and also received collections of animals from distant lands, including primates from equatorial regions of the world. Two of Linnaeus's most important contributions to modern science are his taxonomic system and the **binomial nomenclature,** which is a method scientists use to name plants and animals in descriptive Latin terms**.** Linnaean taxonomy classifies all living things in a ranked hierarchy, from the highest and most generalized category (a domain) down to the species level. Despite recent revisions to Linnaeus's classification levels, the basics of his system are still in use today. In the binomial nomenclature system, **genus** and species are written only in Latin. Scientists use Latin because it is no longer spoken, except by scholars, and therefore will not change over time. In addition, the typeset for the font should be offset (*italics* or underlined) from the main text because the writer is using a different language. In evolutionary anthropology and biology, the first letter of the genus is capitalized while the first letter of all other words is in lower-case letters. For example, the binomial nomenclature for humans is *Homo sapiens.* Thus, we are in the genus *Homo* (human) and our species designation is *sapiens* (wise). Linnaeus believed that he was simply organizing God's creations because at that time, there was no treatise on biological evolution.

Georges-Louis Leclerc (1707–1788) was a French aristocrat, mathematician, and naturalist. Although Leclerc contributed to various scientific fields, one of his most notable contributions to evolutionary concepts was his monumental 36-volume *Histoire Naturelle* (1749–1788). This remarkable series of books described everything known about **natural history** at that time. For example, some of his ideas formed core concepts in what would eventually become the modern science of **biogeography** (Brown and Gibson, 1998), which is the study of where organisms live, at what abun-

Botanist ■ A scientist who studies plants.

Classify ■ The scientific method of placing an organism in a system based on order by classes or categories.

Taxonomy ■ The theory and practice of describing, naming, and classifying extant and extinct organisms.

Binomial nomenclature ■ The scientific method for assigning names to species and genera.

Genus (pl. *genera*) ■ A taxonomic group of species exhibiting similar characteristics.

Natural history ■ The study of animals, plants, and minerals.

Biogeography ■ The scientific study of the geographic distribution of organisms.

dance and why they're there or not there. Leclerc's other primary contribution to the development of evolutionary concepts was the idea that species changed and evolved after they moved away from the place where they were created. This idea is broadly similar to Charles Darwin's Theory of Natural Selection. Jean-Baptiste Lamarck (1744–1829) was also French, a decorated soldier, and, later, an academic. Like Linnaeus, Lamarck was fascinated by the taxonomic classification of plants and animals. His major contribution to evolutionary concepts was a reformulation and specification of a very old idea on how organisms change. Lamarck suggested that individuals lose those characteristics they do not use and develop useful characteristics, and that individuals can pass on these characteristics (or lack thereof) to their offspring. He believed that these changes were the result of an unknown nervous fluid. Moreover, Lamarck theorized that environmental changes could alter behaviour and biological organs. For example, application of Lamarck's ideas would mean that the excessively large muscles (the acquired character) developed by a professional athlete, such as the wrestler Hulk Hogan, must pass on to his offspring (inheritance of the acquired character). Clearly, Hulk Hogan's increased musculature is an acquired trait and not a heritable trait. Modern biologists have labelled these ideas by a variety of terms, including Lamarckism, the theory of "inheritance of acquired characters," and "soft inheritance." Although Lamarckism is no longer accepted by modern biologists, they agree that his published works were integral to the development of evolutionary concepts.

Figure 1.2

Nineteenth-century painting of Carl Linnaeus, dressed in the traditional Lapp costume of Scandinavia. He is holding one of his favourite plants (*Linnaea boreali*), which was named in his honour.

Georges Cuvier (1769–1832) was another aristocratic French naturalist. Cuvier's studies and publications on structural similarities and differences between organisms helped establish the scientific disciplines of **comparative anatomy** and **palaeontology.** These fields compare and contrast tissues of living and extinct organisms. He contributed to the development of evolutionary concepts through his work on the comparative anatomy of extant and extinct mammals. Although modern science accepts extinction as integral to evolutionary processes, in Cuvier's time his idea that extinction has occurred in some animals was in direct opposition to the widely accepted religious concept of **fixity of species,** which is a purely religious idea that a Supreme Being created all living things and that no changes have occurred since the moment of creation. Ideas about the fixity of species assert, quite incorrectly, that organisms do not change (evolve) or go extinct. Cuvier championed a controversial idea known as **catastrophism,** which, among many other things, states that the surface of our planet originated suddenly in the past by geological processes very different from those currently occurring. A key biological element of catastrophism is that it allows for changes in organisms but does not refute Biblical interpretations of the Earth's age. The prevailing view of contemporary European theologians and religious authorities was that the planet was only 5700 years old. Because the Catholic Church in 18th-century Europe wielded enormous political power, going against any of its major teachings was a perilous undertaking. However, Cuvier carefully avoided invoking a Biblical flood as the source of catastrophism, suggesting instead that there were multiple catastrophic events. In fact, he was strongly critical of contemporary evolutionary concepts, such as those proposed by Lamarck. Therefore, Cuvier's major contribution to evolutionary concepts was his assertion that species go extinct.

James Hutton (1726–1797) was a Scottish naturalist and geologist. He made many contributions to the founding of **geology** as a science. Hutton proposed that successive upheaval and erosion of sedimentary rock had been occurring for millions of years and would continue to occur forever. Hutton's ideas would eventually form important components of a **school of thought** known as **uniformitarianism,** which is a geological principle that holds that the Earth was formed and has evolved through the same natural geological processes operating today. Unfortunately, Hutton's complex writing style prevented his published work from receiving the public attention and acclaim he richly deserved.

Charles Lyell (1797–1875), another Scottish geologist, made numerous important contributions to geology, particularly in the fields of **stratigraphy** (the scientific study of how rock layers form) and **glaciology** (the study of how glaciers form). He was an enthusiastic field geologist, making many trips throughout Europe and even to North America. Lyell's three-volume *Principles of Geology* (1830–1833) greatly improved access to and support for uniformitarianism. Before publishing his own thoughts on biological evolution, one of Lyell's greatest, albeit indirect, contributions to the development of evolutionary concepts was his influence on young natural historians in Europe, such as Charles Darwin.

Charles Darwin and the Theory of Natural Selection

Charles Darwin (1809–1882) was an English geologist and naturalist (Figure 1.3). The son and grandson of wealthy country doctors, Darwin entered medical school in hopes of continuing the family medical tradition. Though uninterested in medical studies, he was fascinated by stories about the tropical forest told to him by John Edmonstone, a freed slave from Guyana in South America. Darwin also spoke regularly with local authorities on **zoology,** taxonomy, and basic concepts in biological evolu-

Comparative anatomy ■ The study of anatomical features of animals of different species.

Paleontology ■ The study of fossilized life forms.

Fixity of species ■ A theory that derives from Biblical creation, in which each living thing has always existed and will always exist by God's acts of creation.

Catastrophism ■ The idea that catastrophic events altered geological features and caused the extinction of plants and animals.

Geology ■ The scientific study of the Earth, what it is made of, and how it changes over time.

School of thought ■ A group of people united in their shared belief in some ideas or concepts.

Uniformitarianism ■ A theory that natural processes, such as erosion, operating in the past are the same as those that operate in the present.

Stratigraphy ■ The study of rock layers (strata) and the relationships between them.

Glaciology ■ The study of glaciers and other natural phenomena involving ice.

Zoology ■ The scientific study of animals.

tion. He spent considerable time in the countryside collecting insects, a craze among British naturalists of the period. Not surprisingly, Darwin failed to progress beyond his second year of medical school. He then enrolled in theology at Cambridge University. He spent most of his free time with friends, collecting insects, learning natural history from local authorities, and reading natural history books. Despite these extracurricular activities, Darwin managed to complete his degree. Rather than immediately taking his holy vows, Darwin joined an expedition to survey geological formations in Wales. While Darwin was in Wales, two of his Cambridge professors, John Henslow and George Peacock, recommended him for the unpaid position of naturalist aboard the HMS *Beagle.* The *Beagle* was to set sail for a two-year survey of South America. Darwin was eventually awarded the position after cajoling his father for support and following interviews with the ship's captain. You can imagine his excitement to finally fulfill his dreams of exploration and discovery!

The two-year trip extended to almost five years, as the HMS *Beagle* and her crew visited the eastern and western coasts of South America, the Galapagos Islands, Australia, various islands in the Indian Ocean, and South Africa. While at sea, Darwin read whatever natural history and geology books he could acquire, including Lyell's *Principles of Geology.* Darwin spent much of his time on land, exploring geological formations and collecting thousands of plant and animal specimens. You should note that at this time there were no antibiotics, water filters, or even mosquito repellents. Darwin spent months in environments that challenge even the best-prepared modern explorers and scientists. He made detailed notes on everything he saw and collected. Whenever possible, Darwin sent his collections and notes back to John Henslow at Cambridge University, who made these materials available to a select group of scientists. Consequently, Darwin was a respected naturalist on his return to England in 1836. In 1839, he married one of his cousins, Emma Wedgwood, and settled into the life of a gentleman researcher.

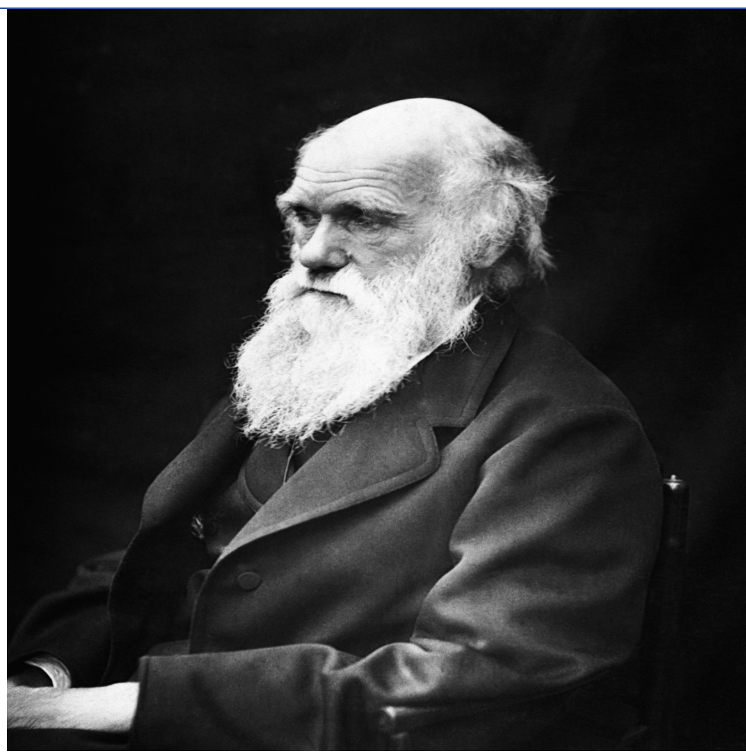


Figure 1.3

A photograph of Charles Darwin in his later years (c. 1869).

Darwin applied himself to determining how species evolved. His research was not composed solely of analyzing dead animals and fossils. Darwin also spoke with anyone knowledgeable about natural history, from dog and pigeon breeders to luminaries in the fields of geology and zoology (e.g., Charles Lyell). He also collaborated with expert naturalists in examining his specimens and categorizing them into distinct species. A bird expert studying Darwin's bird collection from the Galapagos Islands revealed that the birds represented 12 closely related species. Darwin theorized that one bird species must have arrived on the Galapagos from the mainland, and then been altered in some way to eventually become different species. Darwin also read books on economics, such as Malthus's *An Essay on the Principle of Population.* Malthus proposed that human populations could potentially grow at geometric rates whereas food supplies can only increase at an arithmetic rate; he concluded that death, disease, and natural restraint limit human population growth. In other words, many more individuals are born than can possibly survive. Darwin applied certain aspects of Malthus's ideas about competition and checks to human population growth to animals in nature. Combining Malthus's theories with observations he made about the ability of animal breeders to use selective breeding to alter the physical form and behaviour of animals, Darwin formulated ideas about how nature selects for traits in animals. He reasoned that nature selects for or against individuals in the natural world—favourable variants or traits of *individuals* of a species should enable some to better compete in nature. By *selection* Darwin meant that the environment chooses certain physical aspects of an organism, so that some individuals are more likely to survive than others. Thus, if these favourable variants are passed on to offspring, then successive changes over an immensely long time will result in the formation of new species. Less favourable variants and species will disappear. Darwin had formulated the basics of the theory of natural selection!

Years passed between Darwin's first notions on natural selection and the publication of his complete theory. He initially shared only limited aspects of his ideas in letters to select researchers, such as Joseph Dalton Hooker, a famous English explorer with an interest in **botany.** Darwin's reticence stemmed predominantly from concerns about rejection of his ideas by other scientists, such as Charles Lyell. Lyell was, at that time, strongly opposed to evolutionary ideas similar to those Darwin was working on. In fact, some of the most powerful and influential naturalists were adamantly opposed to alternatives to Lamarckism. To avoid conflict, Darwin published books about his trip aboard the HMS *Beagle* and about the zoology of barnacles. He conducted his experiments, engaged in friendly debates with his colleagues about biological evolution, and only secretly worked on a paper describing his theory on natural selection. However, as publication of his theory approached, Darwin's quiet life as a naturalist and country squire was about to change dramatically.

Botany ■ The scientific study of plants.

In the summer of 1858, Darwin was shocked by the contents of an unpublished essay by Alfred Russel Wallace. Wallace (1823–1913) was a British naturalist and explorer who earned his living collecting and then selling organisms from the tropical forests of South America and Southeast Asia. In his essay, Wallace described ideas very similar to those in Darwin's theory of natural selection! Darwin finally felt obliged to present his ideas on biological evolution and natural selection to the scientific community. In 1858, papers by Darwin and Wallace were read at a special meeting of the Linnean Society in London, which created considerable excitement among the attendees. On November 22, 1859, 1250 copies of Darwin's *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life* went on sale in London. Most copies of the book sold on the first day. Today, many scientists consider *On the Origin of Species* to be one of the greatest works of science ever published. Darwin spent the remainder of his professional life revising *On the Origin of Species* and publishing books on various scientific topics.

What did Darwin say in *On the Origin of Species*? Darwin synthesized his field experiences, discussions with animal breeders, experiments, and the work of others into two broad ideas on how species evolve. First, Darwin theorized that all extant and extinct species share a common ancestry, which he eventually called The Tree of Life (Figure 1.4). Closely related species have a more recent common ancestor, while more distantly related species have an older common ancestor. Thus, the supernatural creation of life and the spontaneous creation of species by Lamarckian mechanisms are unnecessary. Darwin saw the process of species formation as a slow, gradual accumulation of slight variations in traits of individuals. Second, Darwin laid out his compelling argument for the power and scope of natural selection. He described his observations on how humans create new variants of dogs though selective breeding, and extended this human selection for domesticates to how nature selects for certain characteristics of individuals, which then compete amongst each other for access to food and mates. Darwin elegantly wrote,

> Owing to this struggle for life, any variation, however slight and from whatever cause proceeding, if it be in any degree profitable to an individual of any species, in its infinitely complex relations to other organic beings and to external nature, will tend to the preservation of that individual, and will generally be inherited by its offspring. The offspring, also, will thus have a better chance of surviving, for, of the many individuals of any species which are periodically born, but a small number can survive. I have called this principle, by which each slight variation, if useful, is preserved, by the term of Natural Selection, in order to mark its relation to man's power of selection. (1859, p. 61)

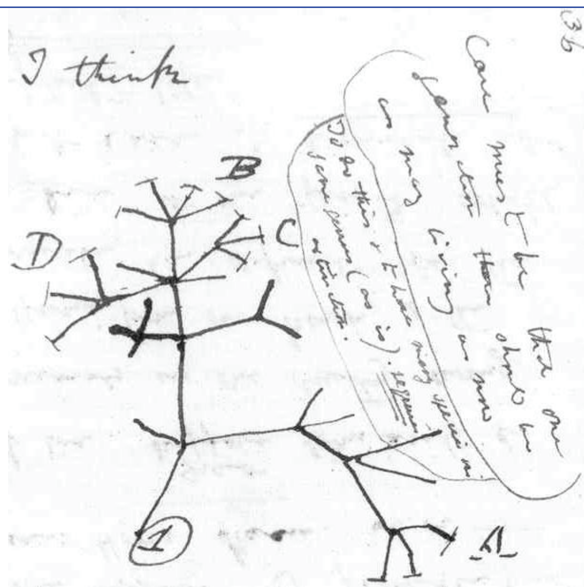


Figure 1.4

A page from Darwin's notebooks, showing his first attempts to illustrate an evolutionary tree, which he termed The Tree of Life.

It is impossible in one paragraph to summarize *On the Origin of Species.* Furthermore, it is beyond the scope of this book to review the considerable differences between how Darwin and Wallace saw natural selection operating. Darwin's knowledge and descriptions of biological diversity were remarkable, even by modern standards. Despite the limitations of 19th-century science, Darwin made accurate predictions about many biological facts that we now know only because of decades of research. *On the Origin of Species* is a remarkably detailed but easily read piece of science, and well worth the time to read and enjoy.

Misconceptions about Darwin's Ideas

There are some common misconceptions about Darwin's published works. Darwin did not originate the phrase, "survival of the fittest." This phrase was the creation of Herbert Spencer, a social philosopher and contemporary of Darwin. Spencer introduced the phrase in *Principles of Biology* (1864) after reading Darwin's *On the Origin of Species.* While Darwin did use it as a synonym for natural selection in the final editions of his book, modern biologists do not use "survival of the fittest" because it was originally intended to apply to human societies and because Spencer favoured Lamarckian concepts over natural selection. It is imperative that you understand that *societies change; they do not evolve.* Misguided attempts to apply Darwin's theory on natural selection to human societies have resulted in **Social Darwinism** and the atrocities of the Holocaust and Rwandan genocide. Proponents of Social Darwinism hold that the strongest or fittest individuals should survive and flourish in society, whereas weak and unfit individuals should be allowed to die. Moreover, "survival of the fittest" implies that organisms gain evolutionary success only by being competitive and aggressive (Figure 1.5), contradicting Darwin's notion that morality has a role to play in human evolution, and that cooperation and other positive social behaviours can also result in evolutionary success (Chapman and Sussman, 2004). Evolutionary anthropologists also criticize colloquial use of this phrase, which incorrectly emphasizes the physical attributes of an organism (e.g., body size, ferocity, and armament). In evolutionary anthropology and biology, **fitness** is a very different thing (Futuyma, 1998).

Darwin's ideas on natural selection and biological evolution resulted in considerable controversy among religious conservatives. These issues tend to revolve around the origins of life, the supposed impacts of Darwin's ideas on religious doctrine, and Darwin's personal views on religion. Some people conflate Darwin's views on the origins of life with the origins of the universe. Darwin's works refer to the evolution of biological systems, not to stellar and galactic phenomena. Second, some religious groups hold misconceptions about how Darwin's ideas on natural selection and biological evolution relate to their faith. **Creationism** became particularly prevalent in secular settings immediately after the publication of *On the Origin of Species.* Most creationists apply a literal interpretation of the Bible to the origins of life, particularly the parts dealing with God's creation of the universe. For example, Young Earth Creationists hold that the earth is only 10 000 years old, rather than the geological estimate of 4.5 billion years. Consequently, creationists see Darwin's work as an attack on fundamental aspects of their belief systems, requiring them to oppose his ideas. The weight of decades of scientific evidence supporting biological evolution led many people to abandon creationist ideas, and to understand that creation themes of the Bible represent symbolic rather than literal truths (Futuyma, 1982).

Social Darwinism ■ The misguided application of the concepts of natural selection and biological evolution to the historical development of human societies, placing special emphasis on the idea of "survival of the fittest."

Fitness ■ The average contribution of an allele or genotype to succeeding generations.

Creationism ■ The largely Christian belief that all life was created by a supernatural deity (typically God), the existence of which is presupposed.

Figure 1.5

Satirical representation of misconceptions regarding the concept of "survival of the fittest."

Some fundamentalist Christians refused to accept that Darwin's ideas have nothing to do with their personal faith. Consequently, these die-hard believers morphed creationism into something called **intelligent design**. Intelligent design or "scientific creationism" represents an attempt to discredit the work of Darwin and other evolutionary anthropologists. This belief system lacks scientific support for an intelligent creator or design; adherents simply seek to discredit Darwin's ideas. For example, despite lacking any data to support the existence of "scientific creationism," some people advocate teaching of this purely religious idea as an alternative to evolution in biology classes in publicly funded school systems. These misguided attempts have failed to gain traction in most school boards, and they have been consistently dismissed by the courts as a duplicitous means of promoting conservative religious opinions. The fact is that Darwin's ideas on biological evolution do not conflict with religion. Why? Because biological evolution deals with biology whereas religion relates to **theology.** In other words, religion has no role to play in b, or vice versa. Thus, when contacted by a young student about the seeming conflict between natural selection and faith, Darwin wrote, "Science has nothing to do with Christ, except insofar as the habit of scientific research makes a man cautious in admitting evidence" (darwin-online.org.uk).

Intelligent design ■ The largely Christian belief that living things occur because of intelligent cause, not as a result of undirected processes, such as evolution and natural selection.

Theology ■ The study of religion from a religious perspective.

Agnostic ■ A person holding the belief that God is unknown and unknowable.

Contrary to what can be found on creationist websites, Darwin was not an atheist; he was an avowed **agnostic.** Darwin's personal religious beliefs were complex and changed throughout his life. Although circumstance and Darwin's faith led him to try to join the Anglican clergy, his scientific discoveries and the early death of one of his beloved children resulted in his rejecting Christian beliefs. Finally, he did not undertake a deathbed conversion to Christianity.

You may be surprised to learn that Darwin did not use the word *biological evolution* at all in *On the Origin of Species.* The closest he came to doing so was in the last sentence of the book:

> There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved. (p. 490)

Darwin did support some aspects of Lamarckism. In fact, he followed Alfred Wallace's suggestion to use Lamarck's explanation of how traits could move from one generation to the next. In later publications, Darwin hypothesized that gemmules passed on traits from one generation to the next. He suggested that gemmules are particles of inheritance produced by organs and carried in the blood. However, experiments by contemporary researchers, including one of Darwin's half-cousins, failed to prove the existence of gemmules. Neither Darwin nor any contemporary scientist knew the biological mechanisms for hereditary variations (i.e., genetics). In other words, no one at that time knew how traits were passed from one generation to the next. A monk in Eastern Europe provided the answer to this vital piece of the evolutionary puzzle.

Introduction to Mendelian Genetics

Gregor Mendel (1822–1884) was a monk in what is the present-day Czech Republic. Mendel was fascinated by physical variations in plants. In his monastery, Mendel experimented with seven physical characteristics of the common pea plant (*Pisum sativum*). For example, his plants produced either yellow or green pods but not yellowish-green pods, purple flowers or white flowers, round seeds or wrinkled seeds, and so on (Figure 1.6). Pea plants are ideal study subjects for inheritance research because a researcher can manipulate their reproduction and maintain large numbers of plants in a small area. Pea plants have both male and female reproductive organs, so each plant can either self-pollinate or cross-pollinate with another plant. Mendel's methods were simple but illuminating. First, he used selective breeding on pea plants so that they always produced only one variant of each trait (e.g., either yellow or green pods). Next, he cross-pollinated the pure plant strains and observed the physical traits of the offspring. Thus, Mendel allowed the pure-breeding plants to pollinate each other, such that the yellow pod plants bred with the green pod plants. The first generation of plants grown from this cross-breeding exhibited only one of the two physical characteristics. In our example, the first offspring always produced yellow pods. Finally, he allowed these offspring to self-pollinate, which produced a second generation of plants. In this second generation of plants, Mendel observed that the physical characteristics were consistently expressed by a ratio of approximately three to one (3:1). So, three out of every four offspring exhibited yellow pods whereas only one of the four had green pods.

Mendel concluded three things about physical variation and heredity. First, an organism's physical traits pass from one generation to the next by "units" or "factors." Second, each individual inherits one "factor" from each parent. Third, a trait may not show up in an individual, although the trait can still be passed from one generation to the next. Mendel reasoned that one "factor" must "mask" another. With considerable pride and excitement, he published results of his experiments in a scientific journal. Unfortunately, naturalists either derided or ignored his conclusions. Mendel's work was largely forgotten until European botanists rediscovered it in the early 20th century.

Figure 1.6

White flower on a common pea plant.

Mendel is now referred to as the "father of genetics" because he discovered the mechanisms of inheritance and because his work led directly to studies that established that biological evolution is the result of genetic variations. In the following section, we explore what really happened in Mendel's experiments.

What Actually Happened in Mendel's experiments?

In time, modern scientists determined what exactly was happening in Mendel's pea plants. The varieties of Mendel's pea plants that are physically distinguishable are now called **phenotypes,** the observable traits of an organism (Figure 1.7). For example, the pod colour phenotypes were yellow and green. We also know that what he called "factors" are actually **genes.** The **genotype** represents the specific genes in an individual or population, whether or not they are expressed physically. In Mendel's experiment, each of the phenotypes was based on a specific genetic code, such as a gene that produces pod coloration. The question arises here as to how some physical features (phenotypes) could seem to skip a generation. You may be familiar with this pattern in that many people describe certain familial characteristics observable in parents passing through offspring to show up again in their grandchildren. In fact, Mendel struggled with how to explain this "skipping of generation" phenomenon in his pea plants. In the end, Mendel concluded that there must be two **alleles** (different forms of the same gene) for each physical characteristic: for example, one allele for yellow pods and one allele for green pods. We can represent the allele for yellow pods with an upper-case *Y* and the allele for green pods with a lower-case *y.* You will see in just a moment that there is a purpose in using upper and lower case.

Phenotype ■ Observable traits or characteristics of an organism

Genes ■ Basic, functional units of heredity.

Genotype ■ Genetic makeup of an organism.

Allele ■ One of several forms of the same gene.

In Mendel's model, each plant inherits one allele for each characteristic from each parent plant. Modern scientists have devised terms for describing these different alleles and how they relate to each other and the physical expression of traits. A **homozygous** condition occurs when an individual organism has two of the same allele at a gene (e.g., YY or yy for colour in the pea plants). Mendel's pure-breeding parent plants were homozygous for each physical trait. Put differently, each parent plant has the genes to produce either green pods or yellow pods. Because each parent plant had two copies of only one type of allele, and those types were different in each of the parent plants, the first generation of plants could only inherit different alleles, resulting in a **heterozygous** condition (e.g., Yy or yY). Only one of these alleles, the dominant one (yellow pod), can be seen in the plant. In other words, when Mendel cross-pollinated green pod plants with yellow pod plants, he got only plants that exhibited yellow pods. Although each of these plants carried the gene for green pods, this genetic material was not expressed by the plants. Thus, modern geneticists define a **dominant** allele, such as yellow pods, as a variant of a gene that prevents another from being expressed phenotypically. A **recessive** allele, such as green pods, is a gene that is expressed phenotypically only when it is in the homozygous condition. Based on these modern definitions, the allele for a yellow seed pod (Y) is always dominant to the allele for a green seed pod (y). Thus, any plant containing the Y (yellow pod) allele will always produce a yellow pod (i.e., YY, Yy, or yY). A plant will produce a green pod only if it inherits the recessive allele from each parent plant (i.e., yy). The gene ratio of Mendel's second generation of pea plants was 1:2:1, which is one homozygous dominant (YY) to two heterozygous dominant (Yy) to one homozygous recessive (yy).

Homozygous ■ Identical rather than different alleles in the corresponding loci of a pair of chromosomes.

Heterozygous ■ Different rather than identical alleles in the corresponding loci of a pair of chromosomes.

Dominant ■ Allele that is fully expressed in the phenotype.

Recessive ■ Allele that is fully expressed in the phenotype only when its paired allele is identical.

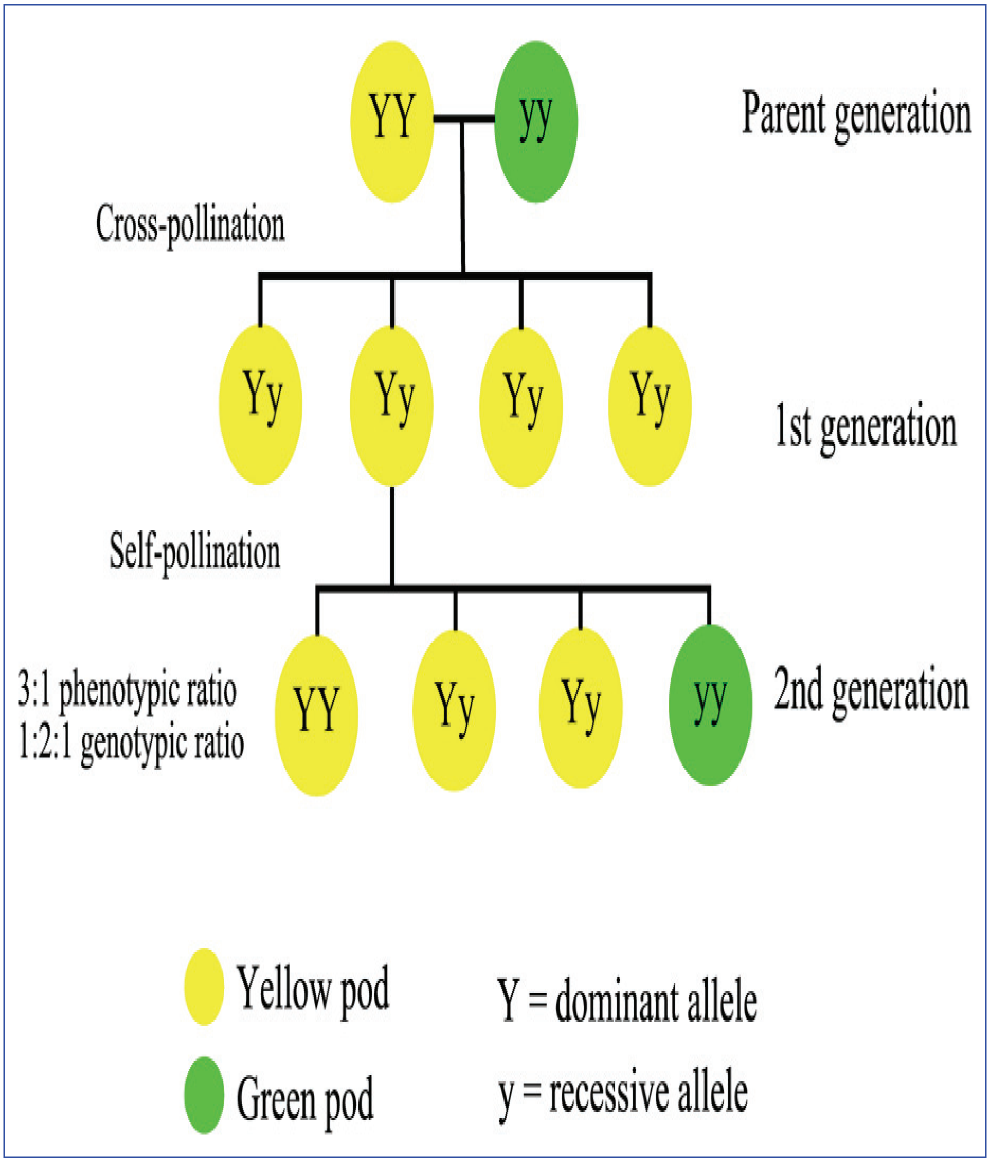


Figure 1.7

Graphical representation of Mendel's experiments with pea pods, focusing on one phenotypic trait (pod color) and its associated alleles (yellow and green).

By luck, Mendel selected pea plants as his test subjects. He was lucky because many, but not all, of the traits exhibited by the pea plants sort into dominant and recessive alleles on one gene. In modern humans, a few sets of physical traits result only from dominant or recessive alleles. For example, cheek dimples are a dominant trait in humans. However, other traits in pea plants and animals do not sort out into purely dominant or recessive alleles. In fact, most traits in humans do not result from alleles of only one gene. Eye colour, for example, is the result of a complex interaction of multiple alleles on multiple genes. These complex patterns are best left to more advanced studies. In the next chapter, we focus our attention on where genes are, what they are composed of, and how genetic information is transmitted within and between populations.

Summary

1. Evolutionary anthropology is the application of modern evolutionary theory to studies of the morphology, ecology, and behaviour of human and non-human primates. Evolutionary anthropologists study living non-human primates (primatology), extinct human and non-human primates (paleoanthropology), human diversity and variation, and the various evolutionary factors that influence human health (medical anthropology).
2. Research in evolutionary anthropology is grounded in evolutionary theory. Evolutionary anthropologists employ, whenever possible, the scientific method. In this method, researchers conduct descriptive, applied, or causal research to test hypotheses derived from evolutionary theory. This research produces quantitative and/or descriptive data.
3. Evolutionary concepts developed over thousands of years in various parts of the world, although the greatest pace of development occurred in 19th-century Europe.
4. Charles Darwin and, to a lesser extent, Alfred Russel Wallace co-formulated the theory of natural selection, which they based on their own studies and those conducted by other researchers. However, Darwin was unable to determine correctly how organismal traits passed from one generation to the next.
5. Gregor Mendel's studies of trait inheritance in pea plants revealed the mechanisms of heredity. Although contemporary scientists ignored Mendel's work, modern scientists credit Mendel as a founder of the science of genetics.

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INTERNET RESOURCES

1. Check out this website about the scientific method:

Science Buddies
http://www.sciencebuddies.org/mentoring/project_scientific_method.shtml
Further information on the scientific method can be found at this Science Buddies website.

2. Learn about some of the authorities on biological evolution:

Researcher Profile: Dr. Craig C. Mello
http://www.hhmi.org/research/investigators/mello_bio.html
Here you will find information about Dr. Craig C. Mello, who won the Nobel prize for his work on RNA.

Wikkpedia: Nicholaas Tinbergen
http://en.wikipedia.org/wiki/Niko_Tinbergen
This site gives information about Niko Tinbergen, Noble prize winner for his work on animal behaviour.

Personal website for Dr. Patricia C. Wright
http://mysbfiles.stonybrook.edu/~pwright/
Learn about Dr. Patricia C. Wright, a John D. and Catherine T. MacArthur Foundation Fellow for her work in primate conservation.

University of Calgary
http://www.ucalgary.ca/~fedigan/fedigan.htm
This website profiles Dr. Linda Fedigan, Royal Society of Canada Fellow for her work in primate behaviour.

Personal website of Dr. Richard Dawkins
http://richarddawkins.net/

This is the website of renowned author, Dr. Richard Dawkins.

New Scientist
http://www.newscientist.com
Catch up on the latest developments in science and technology.

Improbable Research
http://improbable.com/ig
Some of the hilarious yet real research conducted by scientists can be found at this website.

3. Find out more about Charles Darwin:

About Darwin
http://www.aboutdarwin.com/index.html
Here is everything you ever wanted to know about the life of Charles Darwin.

An Online Library of Literature
http://www.literature.org/authors/darwin-charles/the-origin-of-species
Read the original text of Darwin's On the Origin of Species*.*

The Alfred Russell Wallace Page
http://www.wku.edu/~smithch/index1.htm
Everything you ever wanted to know about Alfred Russell Wallace.

4. Find out more about Gregor Mendor:

Gregor Mendel Museum
http://www.mendel-museum.org/
See pictures of Mendor's abbey and gardens, and learn more about his work.

Brother Gregory Investigates
http://www.brooklyn.cuny.edu/bc/ahp/MGInv/MGI.Intro.html
Try out some of Mendel's experiments at this story-based Brother Gregory Investigates website:

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