DARWIN'S BICENTENNIAL CELEBRATION

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This year marks the 200th anniversary of Charles Darwin's birth (12 February) and the 150th anniversary of his book, "On the Origin of Species by Means of Natural Selection". Darwin sailed on the *H.M.S. Beagle* to the Galapagos Islands and other parts of South America (1831–36), which set the stage for his book 23 years later. Among many examples, Darwin observed finches on different islands had developed variations in beak size and shape—related to the type of seeds available for food. The topic of "evolution" remained highly controversial for many decades.

With the 1953 discovery of DNA, a method to sequence DNA in the 1970s, 30 years of advances in molecular biology and genetics, and development of high-throughput DNA-sequencing plus powerful bio-informatics software programs during this past decade—combined with archeology and radioisotope dating of fossils and the rocks found therein—the concept of evolution can no longer be ignored. We now know that DNA is the genetic material, existing as long chains of four bases (adenine, guanine, thymine, cytosine) that make up the cell's chromosomes [see Nebert's *Enquirer* article, January 11, 2009]. Genes (made of DNA) are ultimately made into proteins (long strings of amino acids). Variations of human genes also exist in the mouse, fish, fly, worm, and even yeast and bacteria**;** however, changes in DNA, and thus in the amino-acid sequence of each protein, have occurred slowly over millions of years. If a particular gene product (protein) is, say, 80% similar between human and mouse, 70% between human and opossum, and 56% between human and fish—we can estimate that the last common ancestor**:** between human and mouse was 70 million**;** human and opossum 180 million**;** human and fish 420 million years ago.

We also know that animals, separated from one another for 1 to 3 million years, can no longer interbreed and therefore give rise to new species. What follows are ten examples, among many hundreds that could be cited, of biological discoveries that support evolution. In every case, the overwhelming reason for improvement in a species (or origin of a new species) is **better survival:** finding food and improved reproduction.

- Animals having four **legs** exhibit regions along their vertebrae that give rise to fore-limbs and hind-limbs. We now know that almost all the same genes (from salamanders to humans) are used in both arm and leg formation. So, why don't snakes have limbs? The python's skeleton contains hundreds of similar vertebrae**;** fore-limbs are absent, but actually there are vestigial hind-limbs. One specific gene's expression is known to induce formation of hind-limb buds, while expression of a second gene in snakes then prevents activation of hind-limb growth. By overcoming this inhibitor, scientists in England were able to rescue this pathway—leading to pythons having more than 200 pairs of hind-legs! Early in the evolution of snakes, this inhibitory pathway allowed snakes to develop without legs. For what reason? Obviously to move more stealthily and be more successful at catching prey.

- How could something as complex as our **eye** have developed over millions of years? We now know that many one-celled organisms have "eyespots", containing photoreceptor proteins capable of sensing light. Over more than 3 billion years, we know that "eyes" have evolved independently—somewhere between 40 and 65 times**!** There appear to be two fundamental "designs"**:** one carried by *protostomes* (mollusks, segmented worms, insects and spiders), the other by *deuterostomes* (starfish, jellyfish, sea urchin, and all animals having a spine). In deuterostomes, the basic light-processing unit is the photoreceptor cell, consisting of two fundamentally different types of molecules**:** *opsins* (light-sensing proteins) surrounded by *chromophores* (pigmented cells that distinguish colors). Why would eyes develop over time? Obviously, the better an organism can detect light, or distinguish between "edible" plants and poisonous plants, the better that species can protect itself (finding food, avoiding predators) and reproduce. Box jellyfish have 24 eyes, one set of which shows human-like qualities**!**

- For three decades, scientists have known that fish at the north and south poles are resistant to freezing because of "**antifreeze**" proteins. Now we know that the Antarctic fish antifreeze protein arose from a pancreas-derived gene encoding a protein with 41 repeats**;** this gene arose between 5 and 14 million years ago, which correlates well with the estimated date (about 10-14 million years ago) when the Antarctic Ocean froze. In contrast, the Arctic fish antifreeze protein is derived from a totally different gene and originated about 2.5 million years ago—most likely because of Arctic Ocean glaciation at that time. Here we have different fish species, at two extremes of the earth, needing a protein (at different planetary times) in response to a suddenly cold environment**!**

- **Whales** have lived in water for millions of years but, like us, they are mammals**;** they breathe air and give birth to, and suckle, live young. We now know that mammals originally evolved on land. From fossil studies (especially teeth, and bones of inner ear and limbs), we know that now-extinct creatures called *raoellids* (which would have looked like small dogs) were closely related to "even-toed ungulates" (modern-day cows, sheep, deer, pigs and hippos)**;** they preferred to eat and breed in water. The fossil findings have been confirmed**:** DNA sequence and gene structure data show that whales are more similar to ungulates than to any other creature on earth.

- Decades ago, we learned that the *Archaeopteryx*, a dinosaur with **feathers**, was the earliest known bird. Why should feathers have evolved? No doubt to decrease air resistance while sailing from one tree to another, which became an efficient means to catch prey. Recent fossil evidence has now shown that numerous types of dinosaurs had feathers and, indeed, laid eggs in nests similar to modern-day birds. Geological findings (big crater in the Gulf of Mexico off the Yucatan Peninsula) support the idea that large land-dinosaurs became extinct 65 million years ago because of a meteorite striking the earth and causing sudden planetary cooling. Small feathered dinosaurs undoubtedly survived and gave rise to today's birds.

- "**Co-evolution**" is the evolving of two species that depend on one another. A particular type of ant that eats a special fungus benefits from farming this fungus**;** in turn, the fungus feeds off the ants' droppings. Genes in both the ant and the fungus have evolved together—to ensure greater success (diet, reproduction) for both species—for at least 50 million years. Other examples of co-evolution include**:** fig wasp and the fig tree**;** African moth and a specific type of orchid**;** and certain species of flies that feed on flowers of particular desert cacti. DNA evidence in each case shows animal and plant genes encoding enzymes that break down chemicals from the other.

- The vertebrate **spine** of mammals is best designed for walking on all fours. However, during the past 5 million years, human-like forms began walking upright, as an "adaptation" (safety against predators, efficiency at hunting, and finding food). By age 70 almost every human being today has some degree of arthritic degeneration of the lower spine—because our spines are not properly suited to walking upright.

- **Bacteria** usually double in number every 30 minutes—meaning that one week will give bacteria 336 generations**;** this would be the equivalent of about 84 centuries for humans. Most of us have heard of bacteria "becoming resistant" to a particular antibiotic. Likewise, many **cancers** give rise to cells that become resistant to the chemotherapy being used. Antibiotic-resistance and chemo drug-resistance are both examples of "adaptive evolution".

- **Guppies** were raised in a tank where they could see (behind glass) a predator fish. As the guppies continued to breed in the presence of this "severe visual stress", their coat color gradually changed so that they looked less like guppy prey. This complete change in guppy coat color took nine generations**;** another example of "adaptive evolution".

- Tobacco **budworms** in a cotton field, treated with a pesticide, became resistant to that chemical. These resistant animals were then grown in a Texas lab in the absence of the pesticide**;** after 45 generations, it was found that—once again—these worms became fully sensitive to that pesticide.

These last two examples involve changes so rapid that they do not alter DNA sequences**;** this new exciting field is termed "**epigenomics**".

It was said that Darwin delayed publishing his book for a decade because his wife was extremely religious. Even today, there are some who say that "one must believe either in evolution or in God, but not in both"**;** this cannot be any further from the truth. The definition of "Life" is the insertion of "Order" into our expanding chaotic universe of "Disorder". One can see Order in the formation of a crystal, the folding of a protein, or the process of DNA's sequence leading to a protein's sequence that will allow an organism to adapt to environmental change or selective pressure in order to survive better. Belief in God and our understanding of evolution are mutually compatible.