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by

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The fields of molecular biology and genetics have opened our eyes to the incredible complexity and fascinating intricacy of life. The global scientific community has been brought together as in no other age through computer internet cooperation on projects such as that sequencing the human genome, as well as the mouse, yeast and other species. The minutely detailed research of one lab becomes known to the worldwide community; the work sequencing the human genome, the fifteen year Human Genome Project which envisioned completion by the year 2005, is actually ahead of schedule. The United States NIH (National Institutes of Health) and DOE (Department of Energy) require grant applicants to describe in their applications how and when they plan to make genome data and materials available to the community. If a grant is made, a condition of the award and continuance of funding will be dependent on compliance with sharing (Human Genome Project Report, 1997, p. 75).

Despite the excitement experienced by those familiar with molecular research, perhaps others find themselves apprehensive or threatened by this new knowledge. They see the religious faith of countless people, perhaps weak to begin with, lost once exposed to the anti-theological indoctrination of most higher education. Indeed, some scientists are militantly atheistic and passionately intolerant, seeing as their mission the debunking of the "myths" of religion. Richard Dawkins comes to mind: "We no longer need

to resort to superstition when faced with deep problems: Is there a meaning to life: ...G.G. Simpson put it thus, that: '...all attempts to answer that question before 1859 are worthless and that we will be better off if we ignore them completely.' " "There is such a thing as being just plain wrong" "...faith seems to me to qualify as a kind of mental illness." (From *The Selfish Gene*) And from Francis Crick (of Watson and Crick), "The plain fact is that the myths of yesterday, which our forbears regarded not as myths but as the living truth, have collapsed...yet most of the general public seems blissfully unaware of all this, as can be seen by the enthusiastic welcome given to the Pope wherever he travels." (Crick, 1981, p.164) Some scientists even deny the concept of objective truth. Some, perhaps, have only studied life science at a morphological level, and reach their conclusions without full understanding of the complexity of life, including that of even a single cell. On the other hand, it is the awe-inspiring comprehension of the intricate complexity which has lead others to the conclusion of intelligent design.

It has always been appreciated that there are varying degrees of homology between creatures. In earlier times, the comparisons made between species were limited to those of physical appearance, anatomy, reproductive habits and other readily made observations. Recently, comparisons have been made on a molecular level, with protein studies, cytogenetic analysis of chromosomes, and most recently with DNA. The different methods of comparing creatures have led to different models regarding their closeness. Although controversy abounds surrounding the meaning of such homologies, none question whether or not certain animals seem more or less similar to others.

It has long been appreciated that the great apes appear most similar to man, and of them, the consensus is now that chimpanzees are most closely homologous. An attempt will be made to review the data from the different molecular methods of comparison so as to try and gain an understanding of just how close, on this level, man is to his closest animal compatriots.

In the early years of this century, the Cambridge University bacteriologist George Nutall pioneered molecular systematics by determining the closeness of the relationships between species on the strength of their immune systems' reactions to each other's blood proteins (Tattersall, 1995, pp. 122-123). In 1955 Sanger sequenced the first protein, completing the amino acid sequence of bovine insulin. Following this, proteins were studied in reference to the comparative homology between species. For example, the amino acid sequence of the respiratory protein cytochrome c in humans differs from that in rhesus monkeys, kangaroos, ducks, tuna, moths, and *Neurospora* at 1, 12, 17, 31, 36, and 63 positions, respectively, out of the total 104 amino acids in the human molecule (Hartl,

1991, p. 91). It is not difficult to see that the taxonomic distance correlates with the degree of protein homology. Many other proteins have been studied as well.

As a background regarding DNA, it is to be noted that the human diploid genome contains about 6×10^9 base pairs of DNA, of which only about 2-3% is thought to be coding DNA (that which specifies a polypeptide or mature functional RNA product). There are between 50,000 and 100,000 genes in the human genome. The non-nuclear mitochondrial DNA is a double-stranded DNA molecule 16,569 base pairs long and in the human is strictly maternally inherited.

Four Hominids May Share Ancestor

Comparative cytogenetics, using various banding techniques, has supported genomic homology in four hominoid species, to some suggesting a common ancestor. These include human (*Homo sapiens*), chimpanzee (*Pan troglodytes*), gorilla (*Gorilla gorilla*), and orangutan (*Pongo pygmaeus*) (Yunis and Prakash, 1982). The chromosomes are visibly very similar, with the differences primarily involving structural rearrangements without a loss or gain of euchromatic (gene containing) material. For instance, human chromosome 2 is thought to have arisen from an end to end fusion of two ancestral ape chromosomes (Strachen, 1992, p. 28; de Grouchy, et al., 1972; Clemente, 1989, and many others). This fusion is responsible for the change in the diploid number in humans (46) compared to the great apes (48). The chimpanzee chromosome 12 is homologous to the short (p) and proximal long (q) arm of man's chromosome 2; the chimp's 13 to the distal 2/3 of the long arm of human 2. Hybridization experiments with various probes indicate that the chromosomal type found in human and chimpanzee is the "ancestral one", whereas the 2p homologs in the gorilla and orangutan underwent chromosomal mutations (Baldini, et al., 1993; Arnold, et al., 1994; Haaf and Bray-Ward, 1996) Chimpanzees with trisomy 22 (their equivalent to human 21) have the clinical features of Down syndrome (Luke, et al., 1995).

Based on DNA hybridization studies, the euchromatic regions of the chimpanzee genome share approximately 98% homology with the human (Luke and Verma, 1995). Other DNA hybridization studies reveal that humans and chimpanzees are closer to each other than chimpanzees are to gorillas (Sibley and Alquist, 1987). The heterochromatic regions display considerable divergence. (Heterochromatin remains condensed throughout the life cycle and is presumed to be genetically inactive.) The centromeric region of primate chromosomes contains what is referred to as alpha satellite DNA, long arrays of tandemly repeated DNA sequences.

Sequence similarity between human and great ape alphoid sequences is about 91%. This suggests that this DNA may be rapidly changing, since the homology is lower than that expected in selectively neutral sequence (Baldini, et al., 1993).

Sequence divergence between analogous DNA sequences in closely related primates is somewhat less than 2% (Li and Tanamura, 1987; Strachen, 1992, p. 39). Coding DNA is sometimes 100% identical, for example in the exons of the human and chimpanzee ß-globin gene. Human and mouse have 89.3% sequence homology, which is interestingly higher than the homology between some human genes within the globin family (for example, 79.1% homology between human ß-globin and human ε-globin.) In general, "the sequence homology between different members of a clustered, interspersed gene family is often less than between homologs from different mammalian species." (Strachan, 1992, p. 38)

Another example of this is in some of the zinc finger genes. The great ape homologues of ZNF75 (a human zinc finger gene) were very similar in the sequence determined. The homology was higher than 99% in all three of the great apes compared with man (there was one nucleotide difference between humans and chimpanzees, three between humans and gorillas, and five between humans and orangutans). Three other human ZNF genes (ZNF75A, ZNF75B – a pseudogene, and ZNF75C, located on chromosomes 16, 12, and 11 respectively) have *lower* homology to human ZNF75 (on Xq26), on the order of 86 to 95% (Villa, et al., 1995). This also demonstrates an example of a gene family, thought to have arisen by genome duplication. The duplication event would have preceded the divergence of the great apes from a common ancestor, since all four loci detected in humans are present in great apes and the interspecies homologues are more similar than those within the same species. In fact, two of the homologues are present in cows and horses. The number of differences is compatible with other data indicating greater homology between humans and chimpanzees, than between chimpanzees and gorillas (de Grouchy, 1987; Miyamoto et al., 1988).

Many times nucleotide substitutions are synonymous; in other words, even though the DNA sequence may show substitutions, because of the degeneracy of the genetic code, the amino acid sequence is identical. Non-coding regions are not under such tight constraints and have higher substitution rates. Although the nucleotides sequenced from the exons are identical, the 4,000 base pairs of DNA sequence flanking the 5' end of the human and chimpanzee β-globin genes diverge by about 1.6%, similar to that observed in introns (Savatier, et al., 1985). Different genes also show different rates and types of substitutions in their genes and in the flanking DNA. For example, the ubiquitin (Coenzyme Q) and histone H4 proteins

are the "most highly conserved" (show least divergence between even very distant species) and their genes show a very low rate of non-synonymous codon substitution. On the other hand, fibrinopepetides and the highly polymorphic HLA antigens show a comparatively high rate on non-synonymous codon substitutions (Strachan, 1992, p. 39).

Homology as Evidence

It seems apparent from the literature that the step from seeing homology on the morphologic and now molecular level between species, to assuming they evolved from common ancestors, has been implicit. Homology has been accepted as evidence perhaps primarily because on a molecular level, the current species at least to some seem to be *derived*, and because no other adequate explanation has been evident. The above discussion illustrates the fact that it is difficult to relate the research data without reference to presumed "divergence" from "common ancestors" over "evolutionary time," although some researchers do speak in terms of closeness based on homology but not necessarily invoking presumed common ancestors. Since the proteins and genes sequenced are all on species currently in existence, it is really only conjecture to come up with phylogenetic trees indicating descent based upon differences in sequences, even though complicated mathematical models are often employed. However, some of the molecular data will be presented as an attempt to explain why the theory of evolution has been so compelling.

Researchers see genes which have been "conserved" (meaning maintained with but little change) throughout biological life, for example the genes for histones (proteins involved in DNA structural organization). In the 104 amino acids in histone H4, there are only two differences between cows and peas (Alberts et al., 1994, p. 342). There are families of genes, which appear similar within the species and between species, as noted above, which are thought to arise by duplication and subsequent divergence from a primordial gene. (The duplicate gene can supposedly evolve more freely because the original function continues to be provided by the unmutated counterpart.)

An example of this would be the β-globin gene. Primitive oxygen-carrying molecules, called globins, are found in many marine worms, insects, and primitive fish. In higher vertebrates, there are two kinds of globin chains. "It appears that about 500 million years ago, during the evolution of higher fish, a series of gene mutations and duplications occurred. These events established two slightly different globin genes, coding for the α- and β-globin chains...Still later, during the evolution of

mammals, the β-chain apparently underwent mutation and duplication to give rise to a second β-like chain that is synthesized specifically in the fetus...[this] subsequently mutated and duplicated again to produce two new genes, ε and γ." (Alberts et al., 1994, p. 338)

A cluster of rabbit β-globin genes has an overall organization similar to humans, with two embryonic genes, a pseudogene, and a single adult β-globin gene. The genes are arranged in the order of their developmental expression, and a pseudogene is present between embryonic/fetal and adult genes, as in humans. There is the same pattern in the mouse (Efstratiadis et al., 1980).

The KGF (keratinocyte growth factor) multigene family has also been studied, as well as others (Kelly et al., 1992).

According to Russell Dolittle, prominent in the field of protein sequencing, proteins which have 30% or greater identity can be assumed to have derived from identical ancestors (talk to the American Society of Human Genetics, October 28, 1995). Three dimensional structures (ascertained for example by x-ray crystalography or nuclear magnetic resonance) show resemblances which go further back in time. (The three dimensional structure can look the same although the amino acid sequences are different.)

Chromosomes from different species may initially appear to have very different organizations, for example the mouse has 20 pairs of acrocentric chromosomes, compared to the 23 pairs of human chromosomes. However, high resolution cytogenetic comparison reveals considerable sharing of the banding patterns over small chromosomal regions (Strachan, 1992, p. 29).

Human-mouse comparative genome mapping has identified about 150 conserved segments with nearly identical content. For example, part of the human chromosome 2 contains the same genes in the same order as mouse chromosome 12; another piece of human #2 is homologous to mouse chromosome 17, including the same genes in the same order, and so on. Work with spontaneous and induced mouse mutants has led to the identification of homologous human disease genes (Meisler, 1996; Lalley et al., 1989). "Recently, the homologies between human chromosomes and the chromosomes of pig, cow, and cat have been visualized by cross-species FISH [fluorescence in situ hybridization] with human chromosome-specific DNA libraries...the conservation of synteny between humans and these appears to be three to five times higher than between humans and mouse..." (Haaf and Bray-Ward, 1996, p. 543).

There are genes within genes. Large introns (the DNA which is transcribed into messenger RNA but then spliced out and not translated into protein) occasionally contain whole small genes which are transcribed from

the opposite DNA strand from that used to express the larger gene. The clotting factor VIII gene contains a single small intronless gene within one of its introns. The neurofibromatosis type 1 gene contains three small genes, each with two exons (Strachan, 1992, p. 17).

There are pseudogenes, with homologies to genes but either not coding for a protein, or coding for a non-functional one. These are thought to be the results of evolutionary attempts, or possibly to contribute to evolution because, being non-functional, they would not be under constraints to remain the same. Humans and apes are noted to share pseudogenes, for example ZNF75B. As opposed to being a conventional pseudogene, retaining sequences homologous to exons, introns and immediate flanking sequences, this is an example of a "processed pseudogene." These lack sequences corresponding to introns or promoters and are thought to arise by retroposition (RNA-mediated transposition): mRNA which has already been processed (the introns spliced out) is reverse transcribed back into DNA (called cDNA or complementary DNA) which is then integrated at another chromosome location. The human pseudogene ZNF75B is 99% homologous with that from chimpanzees; those from gorilla and orangutan as well contain no introns nor open reading frame (Villa, et al., 1996).

In hypothesizing another mechanism for creating new function, there is the intriguing phenomenon which has been termed "gene sharing". Here a gene acquires and maintains a new function without any duplication or loss of the primary function, and without any change in its amino acid sequence. There may be changes in the regulation system of tissue specificity or developmental timing. For instance, with crystallin (in the lens of the eye), the same polypeptide serves both as an enzyme and as a structural protein. ε-crystallin from birds and crocodiles is identical in its amino acid sequence to lactate dehydrogenase B (LDH-B_4), and has identical LDH activity. The "two" proteins are in fact one, encoded by the same gene but in different tissues. The σ-crystallin of these same species is identical to another enzyme, arginosuccinate lyase. Some genes encode for three functions (Li and Grauer, 1991, pp. 161-162).

There is the fascinating data about homeobox genes, involved in time-sequenced and tissue-specific embryological morphogenesis. In both vertebrates and invertebrates, homeobox genes cluster in complexes or groups on a chromosome and are arranged in a precise order, the same order in which they are expressed along the antero-posterior body axis (Alberts, et al., 1994, p. 1095; Lufkin, 1996). According to DeRobertis, "All vertebrates have four homeobox complexes each located on separate chromosomes. These complexes probably arose during evolution through duplications of the single cluster of homeobox genes in invertebrates.

Consequently, every human being has four genes that resemble the fruit fly gene *Abdominal-B*, for example, and four others that resemble *Deformed*." (DeRobertis, et al., 1990).

In experiments which cause the *Hox-4.2* gene in the mouse to be expressed more anteriorly, the occipital bones were transformed into structures that resemble cervicle vertebrae, the more posterior phenotype. These alterations are similar to characteristics that specifically distinguish the Agnathans such as lampreys (jawless fishes) from higher vertebrates (Lufkin, et al., 1992). This has been interpreted as "unmasking the ancestral type."

Overexpression of HoxA7 in transgenic mice changes the atlas and dens into a proatlas, present in dinosaurs and still in crocodiles, but not in mammals. This is another example of an "atavistic" change, one resembling phylogenetic origin, or "going back in evolution", so to speak (lecture by Eddy DeRobertis at UCLA on April 15, 1994).

Mechanisms of Speciation Uncertain

Despite the fascinating data of this century, the mechanisms of speciation can only be speculated upon. Chromosomal rearrangements, shufflings and inversions may affect function and homology to only a small degree while presumably contributing to reproductive isolation. Since chromosomes have to pair, large differences in structure between them will make pairing less likely or impossible.

An example supporting the proposed role of translocation as a mechanism of evolution in the apes is provided by hybridization studies with human DNA (Jauch et al., 1992). The human chromosome 7 library stains three different chromosome pairs in the gibbon, with two of these showing an intercalary signal and the third showing a terminal translocation (Weinberg et al., 1990). There is evidence that the evolution of a subset of KOX zinc finger genes on human chromosome 10 has involved three types of genetic events: local gene duplication, gene cluster duplication, and chromosome rearrangements (Tunnacliffe et al., 1993)

There are certain genomic DNA sequences which are human specific. They do not appear to have homologs in any other species and may contribute to the reproductive isolation between man and closely related primates (Strachan, 1992, pp. 39-40).

Much of the non-coding regions of the genome are made up of various repetitive stretches. These are polymorphic regions (having variations between individuals) in humans, with nucleotide variations also noted between human and chimpanzee. These may contribute to intraspecific variability as well (Savatier, et al., 1984).

Taxonomic differences in protein sequences are relatively minor, in general. They seem insufficient to account for the phenotypic and physiologic differences between species. Humans are morphologically very different from chimpanzees, yet the amount of protein divergence between the two species is very small. This has led to the hypothesis that morphological evolution is related more to changes in regulatory genes, as opposed to structural genes (Hartl, 1981).

Theories have emerged attempting to calculate times of divergence from presumed common ancestors. It is to be noted that data concerning divergence times between species are all theoretical. In looking at two species to figure out substitution rates (how many nucleotide substitutions per site per year) the time element is obtained by paleontological data (presumed time of divergence of these two species from a presumed common ancestor, clearly not always a precise proposition). Sometimes divergence time is calculated based on how many nucleotide sites are different for a certain gene between two species. This assumes a certain substitution rate, and that the rate is the same in both species (The so-called molecular clock theory.). However, although substitution rates may be similar between close species, for example humans and apes, or between mice and rats, it appears to be different between humans and rodents (Li and Tanamura, 1987; Li and Grauer, 1991, p. 82; Gibbons, 1995). The great difference in generation time (much shorter in rodents) is probably involved. Also, the DNA repair system may not be as efficient in one species as in another.

A Divisive Concept

The concept of evolution has been devastatingly polarizing. People seem to line up on two sides of a fence over which there seems to be little constructive dialogue. Part of the reason may be that intellectual fields of interest are so highly specialized that people can't understand each other, even within the sciences. And perhaps some avoid seeking knowledge in areas which they find threatening. (This applies to both sides of the evolution fence!) Perhaps the most threatening and least reconcilable concept to traditionally minded people is the notion that the mind and soul are no more than the product of material evolution. Again Francis Crick: "The Astonishing Hypothesis is that 'You', your joys and your sorrows, your memories and your ambitions, your sense of personal identity and free will, are in fact no more than the behavior of a vast assembly of nerve cells and their associated molecules" (Crick, 1994, p. 3). He simplistically speculates (and it seems the whole book pretty much amounts to just this, speculation) that *all* can be attributed to the working of matter. With this in

mind, there will follow a brief section describing the proposed scheme of human evolution.

It is somewhat amusing that the scientific theories involving the emergence of humans are being given Biblical names (although some scientists specifically avoid this). The hypothesis that ancestors of modern humans were localized within Africa has been termed the "Noah's Ark" model (Harding, 1997). The theory of a single human mitochondrial ancestor arising in Africa has been called the "African Eve" hypothesis (Gibbons, 1992; Stoneking, 1997, and others). Although controversial for some years, this hypothesis is becoming established. The single origin hypothesis is gaining favor over the opposing multi-regional hypothesis which postulates that *Homo sapiens* evolved from isolated archaic ancestors on many continents (Cann, 1993; Stoneking, 1993; Batzer, et al., 1994). The single origin hypothesis has also been called the "Garden of Eden" hypothesis (Stoneking, 1997).

The word polymorphism is used to describe alternative forms of genetic characters present in at least 1% of the population (greater than that expected from newly occurring mutations). As these are generally thought to be functionally neutral (there are exceptions), the more shared between individuals or populations, the closer they are; i.e., these shared a more recent common ancestor. It is on the basis of this that studies comparing genetic differences (autosomal, mitochondrial and Y chromosome studies) arrive at hypotheses regarding which extant populations are more ancient. For example, using mtDNA (mitchondrial DNA), ancestral trees have been built indicating an African common ancestor. Also, it is estimated that Africans have twice the diversity of non-Africans, indicating much more divergence and thus implying a longer human lineage (more time in which to diverge) (Gibbons, 1992; Cann, 1993; Jones, 1994). Recent work indicates that the earliest separation of modern humans was between Africans and non-Africans (Mountain and Cavalli-Sforza, 1994; Goldstein, et al., 1995). The age of the human mitochondrial DNA ancestor can be inferred from the amount of sequence divergence among contemporary sequences if the mtDNA mutation rate is known.

The currently proposed time scales indicate that the human mitochondrial ancestor lived between 140,000 and 280,000 years ago (Cann, et al., 1987; Cann, 1993; Tishkoff, 1996; Stoneking, 1997). It is thought that *Homo erectus* (or an earlier *Homo* predecessor which may have evolved into *H. erectus* in Asia) emerged from Africa 800,000 or more years ago, and that they were replaced with subsequent extinction by *Homo sapiens* which rapidly dispersed "out of Africa"; it is unlikely that *Homo erectus* was ancestral to *Homo sapiens* (Cann, et al., 1987; Tattersal, 1995; Wanpo, et al., 1995; Tishkoff, 1996; Stoneking, 1997).

Paleoanthropological data on fossils presumed to be hominid began accumulating during this century prior to the molecular studies. There seem to have been different trends during this time regarding how to assign each fossil (to which genus, which species) and whether or not it is in the line of direct lineage with modern humans. The fashion during the last two or three decades has been one of "synthesis," or the lumping of hominid fossils into very few genera and species. Hominids with obvious morphologic differences were classified as *Homo*, and some as *Homo sapiens*, for instance the unquestionably different Neanderthals. This grew from an assumption that there must be one direct line of descent from ancient hominids to modern man, and the reluctance to recognize the possibility that two or more hominid species could coexist in time. This is at variance with what is observed in non-human species, and is becoming untenable by objective study of the fossil record.

For example, Neanderthals coexisted for a long time with modern *Homo sapiens*. The latter was present over 100,000 years ago, and Neanderthal fossils have been dated to as recently as 50,000 years ago (they first show up between 200 and 150 thousand years ago). The archeological record shows Neanderthals to be less innovative and inventive than modern humans, although they made stone tools and did have large brains. However, neither the size nor the external appearance of the brain, much less brain casts, resolve issues of functions, for example of language. (Tattersall, 1995) This data, confirmed by mtDNA data (Richards et al., 1996), shows that more than two hominid species can be extant at the same time, and that Neanderthals were not ancestral to *Homo sapiens*.

Ian Tattersall, of the American Museum of Natural History, is of the opinion that "if various groups of fossils are distinct enough to be identified by name, you can be pretty sure that you have at least as many species as you have names." Furthermore, he emphatically stresses that "our own living species, *Homo sapiens*, is as distinctive an entity as exists on the face of the Earth, and should dignified as such, instead of being adulterated with every reasonably large-brained hominid fossil that happened to come along." (Tattersall, 1995, p. 219).

Homo is thought to have evolved from *Australopithecus*, the fossils of which date to about 3.5 – 4 million years ago (Coppens, 1994; Tattersal, 1995; Leaky and Walker, 1997). (There is some debate about a newly discovered fossil named *Ardipithicus ramidus*, dated to 4.4 million years ago.) Although there is no smooth sequence of intermediates in the fossil record, there are quite a few hominid fossils being evaluated. The divergence from the great apes is generally thought to have occurred four to

six million years ago (Li and Grauer, 1991; Tattersall, 1995; Tishkoff et al., 1996; Stoneking, 1997).

The prevailing dogma is that all life forms on earth (extant and extinct) share a common origin, which was one or a few organisms, or perhaps even cells, living approximately three and a half billion years ago. The apparent relatedness of all life has led to the concept of a common origin; conversely, once a common origin is assumed, all plants, animals and bacteria are seen to be related to each other by descent and the reconstruction of phylogenetic relationships is pursued based on degree of differences. Closely related organisms are presumed to be descended from more recent common ancestors. A difficulty in reconstructing phylogenetic trees is that since divergence from a common ancestor, the species being evaluated have all had time to evolve and change. For example, if humans and chimpanzees descended from a common ancestor, they have both changed since that divergence. (It is a misunderstanding to imply that humans evolved from chimps, as they are extant simultaneously.) Determining which features were present in the common ancestor, however, becomes quite complicated.

Mechanism of Evolution Unclear

The mechanism by which creatures may have evolved is by no means clear. Darwin proposed small mutations with selective advantage. However, although adaptation to environment is widely observable, speciation requires genetic changes affecting reproductive compatibility, not adaptation particularly. Some favor a theory of neutral mutations, responsible for a change but without a selective advantage. Most forces seem to be involved in maintaining the genome unchanged, as mutations are generally harmful; DNA repair mechanisms and the reproductive isolation resultant from mutations of sufficient significance tend toward minimizing changes in the genome. The absence in the fossil record of the smooth sequences of intermediary forms expected from "phyletic gradualism" has led to the theory of "punctuated equilibria ," in which evolutionary change is seen as episodic.

There are many observations which the theory of evolution does not adequately explain. One stumbling block observed by evolutionists themselves is that there does not seem to be enough time since the beginning of the earth (assumed to be 4.6 billion years ago based on radiometric dating) for evolution from inorganic matter to organic (life). Mathematical models have pointed out that there was insufficient time from the beginning of the earth to the appearance of the first cellular organisms about 3.5 billion years ago to allow hypothesizing evolution of organic life

from an inorganic "prebiotic" soup. Some of the theories proposed to get around this seem pretty desperate; perhaps the most entertaining is that expounding space seeding. None less than the aforementioned Francis Crick of Nobel Prize fame advanced a theory called "directed panspermia," by which advanced extraterrestrials sent primitive life forms to earth in a spaceship. The theory "postulates that the roots of our form of life go back to another place in the universe, almost certainly to another planet; that it had reached a very advanced form there before anything much started here; and that life here was seeded by microorganisms sent on some form of spaceship by an advanced civilization." (Crick, 1981, p. 141) Would it not take a smaller leap of faith to believe in God? In fact, earlier in the same book Crick concedes, "An honest man, armed with all the knowledge available to us now, could only state that in some sense, the origin of life appears at the moment to be almost a miracle, so many are the conditions which would have had to have been satisfied to get it going." (p. 88)

For about two and a half billion years after the appearance of the first cells (roughly two-thirds of the entire history of life on earth), all organisms were single-celled procaryotes (simple cells without nucleus or organelles). The pre-cambrian record (600-700 million years ago) does exhibit some multicellular animals, but resembling no modern design and unlikely to be ancestors. In rocks just a little younger, there is what has been termed the "Cambrian Explosion." Nearly all modern phyla are represented, the four great known arthropod groups were there as well as sixteen additional previously unknown arthropod designs and about fifteen or more unique anatomies not falling into known phyla. The subsequent 500 million years have yielded no new phyla. And yet detailed study, for example, of the soft-bodied fossils of the Burgess Shale of Canada, give no indication that these animals were primitive in the sense of simple (eyes, legs, gills, and the like, all require extremely complicated cellular mechanisms; see below). In fact, it would have been impossible, based on body design, to predict which would become extinct. Apparently at this early time there were numerous possibilities, "each sensible in itself after the fact, but each utterly unpredictable at the outset." (Gould, 1989, p. 233) They appear to have been decimated, not because of inferiority of design, but by the "multifarious possibilities of historical contingency" or chance. Just one of the many examples is the strange *Opabinia*, with five eyes, a frontal nozzle and gills above lateral flaps – not fitting into any known phylum.

Why no more basic body plans? Was there a genomic plasticity early on that was lost? It is difficult to imagine a model. However, the Victorian ideal of evolution (and generally all that comes with the passage of time) as necessarily manifesting "progress" is severely challenged.

Returning to the issue of complexity, comparing different species, even on a molecular level, cannot show how a complex system achieved its function. Biochemist Michael Behe has elucidated for the lay public the extreme complexity of cellular mechanisms through understandable examples, describing in detail the blood coagulation cascade, and scratching the surface regarding the incredible molecular complexity of bacterial flagellae. These are examples of systems which are *irreducibly complex.* By irreducibly complex, Behe means "a single system composed of several well-matched, interacting parts that contribute to the basic function, wherein the removal of any one of the parts causes the system to effectively cease functioning. An irreducibly complex system cannot be produced directly (that is, by continuously improving the initial function, which continues to work by the same mechanism) by slight successive modifications of a precursor system, because any precursor to an irreducibly complex system that is missing a part is by definition nonfunctional." (Behe, 1996, p. 39) This is a powerful argument for intelligent design, an argument based on scientific evidence. The question of the identity of the designer does not have to be addressed by science.

So far there are no detailed models of exactly how small or even big genetic changes could have lead to the variety of life we observe. There is no real way to test this, at least not yet, and in fact it has not been possible to experimentally create a new species.

How can man and the animals be so seemingly similar on a molecular level, and yet have such self-evident differences? Man and chimp may be closer than chimp and ape, and yet there is a great abyss that even a small child can see between man's capabilities and the smartest chimp's. Can we seriously say, like one of Professor Janet Smith's students, that cats don't play in symphony orchestras because they're just not interested? (recorded talk of Dr. Janet Smith) Or do we not better relate to the statement of the late Dr. Jerome LeJeune, that he has never overheard monkeys at the zoo discussing where to send their kids to college? Can we assume that "regulatory genes," or better neurotransmitters, better "wiring" of the brain, can give rise to thought, self-reflection, the ability to abstract? Is it not common to the tenets of both science and philosophy that like should beget like (i.e., matter should beget only what is physically measurable in space and time)?

Man and animals differ fundamentally in that man has the capacity to analyze himself, to step out of himself and observe himself. Man as an animal finds himself full of instincts, but he also has a freedom to choose against them, even to his own detriment. This can be done because of foolishness or because of altruism; nonetheless, freedom of will is a distinctively human attribute. The choices a person makes participate,

along with genes and environment, in the formation of the end product. Disciplining the mind or body, moral choices, association with certain people instead of others, make irrevocable differences in terms of the person one becomes. The capacities of the mind, body and personality have a plasticity upon which the person can operate, not just which are operated upon by forces totally beyond control. The raw materials can be formed in a nondeterministic way.

Man has the capacity for disinterested love, and some would argue that to the degree that we manifest a preferential option for the poorest and weakest amongst us, the more truly human we are. This has been countered by others, maintaining that even actions which on the surface appear self-sacrificing are in reality programmed for by self-serving genes. Even though many human actions are far from truly free, being instead the result of coercion or of the reflexes of a personality which has failed to develop the capacity for true thought, most people have observed human actions which do seem free.

Capacity to Communicate

Animals in general have varying forms of communication. Is man's capability for language just an improvement, but fundamentally still within the same spectrum, or is it to be accounted for by some other factor than just a better brain? As mentioned, the surface of the brain, or a cast of it, is not helpful. However, studies have shown that to make the basic sounds of articulate speech, the larynx needs to be situated low in the throat and connected to the oral cavity by a long pharynx. Primitive hominids have flat skull bases, reflecting a high larynx and short pharynx, in contrast to modern human (Tattersall, 1995, p. 211).

There is also some interesting linguistic data. "Amazingly enough, when the world language tree is put next to the genetic tree, they look rather similar. Both come to the same root in Africa and both show the same split between Australasia and other Asian peoples. Perhaps this shows that language itself dates back to the very beginning of humankind." (Jones, 1994, p. 154; cf. Cavalli-Sforza et al., 1988).

We humans are notorious for the emotional content of our lives, for nonphysical "feelings" painful or pleasurable. And we are not just physically vulnerable but psychologically as well. Each of us knows how fragile we are, how a word or look from another person can exalt us or devastate us. What power we have over each other! Is there anything comparable in the animal kingdom?

One would think that the high degree of genetic homology between man and chimp, far from threatening, should increase our conviction in the

existence in man of something which cannot be defined by, and is outside of, the purely physical or material. This attribute is called by different names; some of us know it as the soul, or more precisely, the spirit. Science can only examine matter, but it should be able to deduce something which cannot be accounted for by matter. Is it not provocative that Rebecca Cann, who did much of the initial mtDNA work leading to the African Eve hypothesis, should observe, "The mystery of what caused populations to expand 100,000 years ago, either due to a new culturally based, or a biologically based mixture of these adaptations, continues." (Cann, 1993, p. 82) Also of interest is the observation regarding the adaptations in nature; some are suboptimal, but "some traits appear to be superoptimal. For instance, the capacity of the human brain to engage in mathematics, art, and literature seems to be far in excess of the demands of the selective pressure of the environments in which it evolved." (Mettler, et al., 1988 p. 266)

Perhaps future research, for example, in geniuses will help elucidate some of these issues. There does not yet seem to be evidence for enhanced performance (either mental or physical) being attributable to a beneficial mutation, nor has it been noted that geniuses pass on their remarkable abilities (i.e., the trait does not seem to be dominant). Most polymorphisms (considered normal variants in the population) are thought to be neutral. Most mutations are deleterious, giving rise to a myriad of diseases. Because of the extreme complexity and multitudinous interactions of cellular mechanisms and structural arrangements, it can be appreciated that a change in one component would result in inefficiency, abnormality and sometimes lethality. Primary, secondary, tertiary and even quaternary structures all depend on the integrity of the genomic code at the DNA level, and there are multiple cascades of interactions. It is true, however, that most research has been done on "abnormals", not on "supernormals" of the caliber, for instance, of Mozart. Will the capacity of geniuses be found to reside at the molecular level, or the spiritual? Certainly an intact physical brain is a prerequisite, but we will have to wait for the answers to these questions.

Nonetheless, it is the spirit, not the body, that knows and loves, that wills to act, that has the capacity for creativity. "The souls, the life-principles, of plants and animals produce no vital activities which rise above matter...But the soul of man not only animates the body, it has powers of its own utterly outside the possibility of matter...it is what no other soul is, a spirit." (Sheed, 1981, p. 60) Certainly it uses the body; it is its instrument. But ideas are not material. They have a meaning separate from any cerebral activity which has accompanied them. They, like the spirit from which they spring, do not take up space, nor have shape, color,

size, or weight. But they are not nothing; in fact, ideas and thought, along with love, are most powerful. These and our ability to be creative are the most important aspects of our existence.

"If we are continuously producing things which have no attribute of matter, it seems reasonable to conclude that there is in us some element which is not matter to produce them. This element we call spirit." (Sheed, 1981, p. 11)

Can we reconcile the idea of evolution with the Christian faith? We hold that Adam and Eve had free will and could have chosen to be obedient and yet we acknowledge God's foreknowledge of their choice since He is outside of time. One might envision that the matter of the universe was instantaneously created at the beginning of time in some primordial state by God. Since we observe that the nature of the material universe is to change, for instance some species have become extinct even during our own lifetimes, it does not seem logical that God would have created a static finished product. Endowed with innate laws this matter would spontaneously and continuously change, arriving at the state of the universe we observe today. That is not to say that God does not have complete sovereignty nor that we have not seen Him act during history, especially salvation history. However, for the most part, He does not seem to suspend His laws.

Can we also envision physical evolution of living creatures (past the cell stage at least) as having been determined by the natural laws God put into place, including their being subject to such contingencies as meteorites hitting the earth, ice ages, temperature changes and the like? (Current science does seem to indicate the *creation* of the first life, not its evolution from the inorganic). In the same way God "foresaw" Adam and Eve's choice He would have known that a being capable of maintaining a spirit would evolve, or be derived. That man was made "in the image and likeness of God" refers to the soul, not the body. At which time God first granted this spiritual soul to a creature was when "man" in the holistic sense (an animal with a spiritual soul) was first created.

One of the big questions would be whether evolution was absolutely determined by the primordial arrangement, or just foreseen to occur as a possibility among many. Is it necessary to invoke God's direct intercession at each step of molecular change or mutation? Do we need to say that evolution was directed? Man's free will indicates God's willingness to abdicate control over at least some of His creation.

Openness to the possibility of physical evolution is not new in the Catholic faith. St. Ambrose, in his homilies on the six days of creation, said, "And perhaps they may say: Why did not God, in accordance with His words, 'He spoke and they were made,' grant to the elements at the same

time as they arose their appropriate adornments, as if He, at the moment of creation, were unable to cause the heavens immediately to gleam with studded stars and the earth to be clothed with flowers and fruit? That could very well have happened. Yet Scripture points out that things were first created and then afterwards put in order..." (Ambrose)

St. Augustine did not view Genesis as being a literal description of creation. In *De Genesi ad Litteram* he speculated that in the beginning God created the material "seeds" of the universe, and then there followed the transformation and ordering of these initial "seeds."

Gilkey's interpretation of Augustine is that "it was impossible to interpret it [creation] in a completely literal way, since the creation of all things included the creation of time, and so could not itself have taken place over six days of time." (Gilkey, 1985, pp. 225-226) All of the material of the universe is understood to have been created *instantaneously*.

Cardinal Newman wrote, "In view of the orthological similarities between men and apes, the *onus probandi* rested on those who denied, rather than on those who affirmed the existence of a genetic connection between them." (quoted in *Los Angeles Lay Catholic Mission*, January, 1997).

Pope Pius XII's 1950 encyclical *Humani generis*, in #36, states "For these reasons the Teaching Authority of the Church does not forbid that, in conformity with the present state of human sciences and sacred theology, research and discussions, on the part of men experienced in both fields, take place with regard to the doctrine of evolution, in as far as it inquires into the origin of the human body as coming from pre-existent and living matter – for the Catholic faith obliges us to hold that souls are immediately created by God." We would not speak of the "evolution of the soul," or refer to it as being "given" to the child by the parents; each man's soul is created by God. Some sentences later, in #37, "When, however, there is question of another conjectural opinion, namely polygenism, the children of the Church by no means enjoy such liberty." The latter theory is as aforementioned loosing ground among researchers.

Pope John Paul II's message on evolution to the Pontifical Academy of Sciences on October 23, 1996, referring to *Humani generis*, states, "Today, almost half a century after the publication of the Encyclical, new knowledge has led to the recognition of more than one hypothesis in the theory of evolution. It is indeed remarkable that this theory has been progressively accepted by researchers, following a series of discoveries in various fields of knowledge. The convergence, neither sought nor fabricated, of the results of work that was conducted independently is in itself a significant argument in favour of the theory." And later in the address, "The sciences of observation describe and measure the multiple

manifestations of life with increasing precision and correlate them with the time line. The moment of transition to the spiritual cannot be the object of this kind of observation, which nevertheless can discover at the experimental level a series of very valuable signs indicating what is specific to the human being. But the experience of metaphysical knowledge, of self-awareness and self-reflection, of moral conscience, freedom, or again, of aesthetic and religious experience, falls within the competence of philosophical analysis and reflection, while theology brings out its ultimate meaning according to the Creator's plans." (English translation from the French, obtained from internet: http://www.vatican.va)

It then seems that it is not necessary to believe one must make a choice between God and science. In fact, it would not be logical to think that metaphysical truth and scientific truth conflict, even though when limited by insufficient data or understanding, they seem to.

> Many of our contemporaries, however, seem to be afraid that a closer relationship between religion and man's activity will injure the autonomy of men or societies or the different sciences. If by the autonomy of earthly realities we mean that created things and even societies have their own distinctive laws and values, which must be gradually identified, used and regulated by men, this kind of autonomy is rightly demanded. Not only is it insisted on by modern man, it is also in harmony with the design of the Creator. By the very fact of creation everything is provided with its own stability, its own truth and goodness, its own laws, and orderly functioning. Man must respect these, acknowledging the methods proper to each science or art.
>
> One should therefore deplore certain attitudes of mind which are sometimes found even among Christians because of a failure to recognize the legitimate autonomy of science. These mental attitudes have given rise to conflict and controversy and led many to assume that faith and science are mutually opposed. (from *Gaudium et spes*, #36, Second Vatican Council)

John Paul II has written, "Only a dynamic relationship between theology and science can reveal those limits which support the integrity of either discipline, so that theology does not profess a pseudo-science and science does not become an unconscious theology. Our knowledge of each other can lead us to be more authentically ourselves." (quoted in Skehan, 1990) And from a scientist: "My own feeling is that although biology may tell us a lot about where we came from, it says nothing about what we are." (Jones, 1994, p. 210)

Scientific truth has always flourished in the cultures seeking metaphysical truth. Thus, our search should be for *all* truth, our goal to personally integrate it. And although many argue that metaphysical beliefs are all very fine, for those who choose to think about them, whether or not men choose to think about them impacts us all.

If indeed man is more than just an animal, then it follows that he cannot behave is if he were. If we all do not agree on this (and it seems that precious few do), then the future holds for us not only the present horrors of abortion, creative new reproductive technologies and euthanasia, but also the spectre of cloning humans. That is not to say that there are not ethical ways to clone genes or to develop gene therapy, but without clear commonly held ethical principles, humans will be cloned and other violations to the dignity of the human person will continue to escalate. The prohibition against *using* any other human being, and the positive command *to love*, become understandable as not just arbitrary or optional, but imperative.

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