NOT SO BLIND A WATCHMAKER

RICHARD D. LUMSDEN*

Abstract

Structural and operational principles underlying the organization of the vertebrate retina and bacterial flagellar apparatus are reviewed in the context of William Paley's classic intelligent designer vs. Richard Dawkins' contemporary "blind watchmaker" interpretations of biological origins and diversity. The significance of inverted retinal microanatomy and retinocytophysiology is diagnosed. In the process, Dawkins' riposte to Paley is refuted. The second example is more contemporary. In terms of biophysical complexity, the bacterial rotor-flagellum is without precedent in the living world. To the micromechanicians of industrial research and development operations, it has become an inspirational, albeit formidable challenge to the best efforts of current technology, but one ripe with potential for profitable application. To evolutionists, the system presents an enigma; to creationists, if offers clear and compelling evidence of purposeful intelligent design.

Introduction

Among the most prized pieces of evidence for the historical presence of human beings that can be found in an anthropological dig are tools. A skilled investigator can readily distinguish such artifacts (man-made objects) from natural objects, e.g., curiously weathered rocks, by indications of manufacture (chipping, beveling, etc.) and of purposeful design (i.e., preconceived utility). The indicated parameter is *intelligence*— in this case, the capacity to conceive in the abstract the need for the implement, thus its application, to engineer a design appropriate to the task, to identify the suitable material(s), and to devise the technique(s) for its construction; in a word, *invention.*

In the earth's biosphere, intelligence of that sort is arguably unique to human beings (Morris, 1984). Occasionally we witness "tool using" animals—an example would be otters using stones to crack the shells of the mollusks they eat [while floating on its back, the otter pounds the shellfish against a stone it has placed on its chest]. However, it is likely that otters acquire this behavior empirically. Certainly there is no creative process involved (on the otters' part) where the production of the instrument itself is concerned, though the activity may strike the observer as "intelligent." The same might be said for nest building by birds, the constructions wrought by social insects, etc. But where the interpretations of some animal behaviorists on this subject of intelligence are concerned, and others who would take it to the cellular level, even, let us be wary of anthropomorphisms (Lumsden et al., 1992, 1993). Evidence of intelligence lies more in design—the inventive aspect—than use alone. As Augros and Stanciu (1987) note, the executor of a purpose need not have an intellectual understanding of the phenomenon. Zoologically, many purposes are executed from a preprogrammed intrinsic cause, are a prescribed function of endogenous anatomy and physiology, or are directed reflexively by sense perception [see Tinbergen, 1989, for many pertinent examples]. In any event, here the rocks remain unadulterated rocks; in the otter's paws they do not become contrived mallets or anvils. The dexterous otters only use the rocks, albeit cleverly, that are available. The same would be true of an *Ammophilia* wasp that uses a pebble to seal its nest, even though it literally uses its head to hammer the pebble into place.

*Richard D. Lumsden, Ph.D., The Master's College, Santa Clarita, CA 91322-1450.

Thus, tools, fashioned by design to one degree or another of intricacy, are diagnostic of creative intelligence, therefore of an *intelligent cause.* It follows that the more sophisticated the tools are, the greater the intelligence behind them. Thereby do Archimedes, Leonardo, and Edison warrant our accolades. From the engineering standpoint at least, the wheel, considering all its formats, might be regarded as the penultimate product of innovative endeavor. Imagine the excitement if a wheel—of any kind—were one day found beneath the sands of Mars. Assuming it would not be litter traced back to an earth-based exploratory mission, SETI (Search for Extraterrestrial Intelligence, budgeted for the present decade at $100 million) would be vindicated. Irrespective of its elemental material composition or size, or how it might have been used, no one would conclude that a wheel, on Mars or anywhere else, merely happened. Now what if the wheel was found as a component of a complex entity, i.e., one of multiple, integrated components, and therein accomplishing definable work? Physical happenstance would be even less credible an explanation.

Biologists who contend that life is solely a product of stochastic, purely naturalistic, physico-materialistic processes are faced with the paradox that nowhere is sophistication more apparent than in the intricate construction of living things. If the discovery of wheels on Mars would be greeted as proof of intelligence other than earthly humankind, how about finding powered wheels—spinning at thousands of rpms—in biological systems as components of an engine? Should not this set one's intellectual wheels turning, so to speak, where biological origins would be pondered?

Argument from Design vs. the Panda Principle

William Paley was appropriately impressed (well before the advent of electron microscopy) with the high complexity, specificity, and low probability of the living world. Paley, seeing that it all required a special explanation, began his treatise on *Natural Theology* (Paley, 1802) with an anecdote—that of stumbling across a watch while crossing a heath. Paley rhetorically asked how such an intricately formed object—replete with finely honed gears, sprockets, and springs (all predicated on the principle of the wheel)—could have come to be in a natural setting. Besides the owner of the lost watch, of what would it be evidence? Why, irrespective of where the watch was found, or how it got there, the very preciseness and intricacy of its works would be

immediate and clear evidence of the existence of a *watchmaker.* Watches (ergo wheels) do not just happen.

Following this analogy, Paley went on to extoll the structure and function of the human eye—as an instrument for vision, surely it had an intelligent designer, just as telescopes, microscopes, and spectacles had been intelligently designed to assist it. A more apt analogy would have been the camera, but that had yet to be invented. The "Argument from Design" for the existence of the Creator God (Romans 1:19-20) behind nature was compelling at least for a time to all but the most hardened skeptics [see, e.g., Mackie's (1982) discussion of 18th century philosopher David Hume's view of theistic causation as an unnecessary, even counterproductive superstition, the view that Paley would rebut]. Even Charles Darwin, who 50-odd years later would otherwise argue for a purely natural (vs. supernatural) origin of biological entities and their diversity, was perplexed by the example of the eye (Darwin, 1859, 1888). Yet it has been said (see Dawkins, 1986. p. 6) that Darwin made it possible to be an intellectually fulfilled atheist.

Apparent ingenuity in biological structure still persists as an argument for purposeful design (e.g., Denton, 1986; Augros and Stanciu, 1987), especially when incorporated in solutions to problems comparable to those confronting our own technology. Not the least of the examples cited remains the eye (see Denton, 1986, pp. 332-333). And doctrinaire evolutionists persist in derisive analyses of creationist teleology. Thus does Oxford's Richard Dawkins (1986) present a contemporary "rational" (Hume-anistic) alternative to Paley's Watchmaker—- *viz.* the purposeless, mindless, sightless forces of physics, chemistry, and natural selection. He, like Peter Atkins (1981), argues that the evolution of complex things is inevitable once the requisite physical conditions are in place. Thus, it was inevitable, we are to suppose, that one day dinosaurs would take to the air and cows (more specifically, one of their ungulate ancestors) would go submarine (reference scenarios for the evolution of birds and whales, respectively). Sooner or later, eyes would develop from the primitive photoreceptors of "lower organisms." And what else but naturalistic trial and error would account for what Dawkins (see also Gould, 1980, 1986) identifies as the *imperfections* in biological structure including that of the human eye, but a *"blind* watchmaker"? Surely, an omnipotent, omniscient Creator would not have gotten the layout of the human eye so confused, as Dawkins contends is the case for the microanatomy of the retina (Figure 1). Paley's respect for *intelligent* design of the eye was misplaced—the photoreceptive processes of the rods and cones face *away* from the incoming light toward an *opaque* pigment layer at the back of the eye! Light first strikes not the photoreceptors but a tangle of neurons lying *between* the lens and layer of rods and cones; the placement of the neurons transmitting the visual signals to the brain is thereby *backward.* Dawkins (1986, p. 93) conjectures that with such restricted passage ". . . through a forest of connecting wires" the light ". . . presumably [suffers] some attenuation and distortion . . . [a] principle . . . that would offend any tidy engineer!"

Professor Dawkins (1986) patronizingly refers to Paley's argument as made nonetheless ". . . with pas-
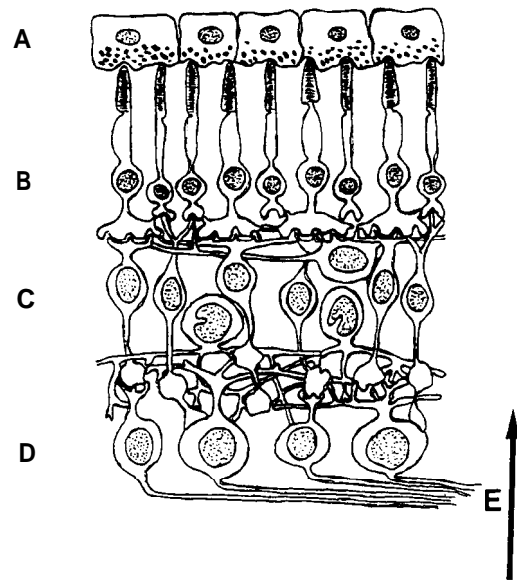

Figure 1. Microanatomy of the mammalian retina. A, pigment epithelium; B, photoreceptors (rods and cones); C, interneurons; D, ganglion cells; E, axons (to optic nerve). Arrow denotes direction of the incident light. After Alberts et al. (1989) and Bloom and Fawcett (1975).

sionate sincerity and . . . informed by the best biological scholarship of his day . . ." (p. 5), as he goes on to remark that "Natural selection . . . which we now *know* is the explanation for the existence and apparently purposeful form of all life, has no purpose in mind" (p. 5, emphasis added). But, of course, the eye works. Evolution makes the best of things after the fact. Per Harvard's Stephen Jay Gould (1980, p. 13) "the proof of evolution lies in its imperfections that reveal history," the view expounded in his "panda principle" (Gould, 1986). Paraphrasing Francois Jacob, he remarks (1980, p. 26) that nature is an "excellent tinkerer, not a divine artificer" and takes ". . . paths that a sensible God would never tread" (p. 20).

The Eyes Have It

Where the best biological scholarship of our day is concerned, we are fortunate indeed that Dawkins was not commissioned to design our eyes, since given the optical physics, photochemistry and neurobiology involved, their present construction is, in fact, the best way they could have been put together! While a rod cell is responsive to single photons (Baylor et al., 1979), visual receptors have a threshold of intensity below which light is an ineffective stimulus. But more is not always better. The human eye is only weakly sensitive (respective of discrimination) to *direct* bright light compared to indirect (therefore lower intensity) light, even when appropriately focused by the lens and apertured by the reflexive iris/pupil diaphragm (see principles of the Abbe condenser); thus the significance, from a design standpoint, of light at reduced intensity off the pigment epithelium impinging onto the "backward-facing" photosensitive elements of the rods and cones. The pigment granules receive the light after its transversal of the *translucent* neuronal layers (Hamilton, 1987) that overlie the rod and cone layer and photoreceptor layer, thus preventing its scattering from the

external ocular tunics and confusion thereby of the image. Moreover, the human eye works within the 700 down to 400 nanometer (nm) wavelength range, thus short ultraviolet (uv) can be filtered (by passage through the overlying neural components) without consequence [note, the penetrating power of uv light is markedly inferior to that of white light]. Many invertebrate eyes, however, operate as well in the 300 nm range, and their microanatomy is oriented accordingly (forward-facing receptors, etc.). Dawkins opines that the eye of cephalopod mollusks (octopi and squids), while otherwise resembling that of vertebrates, is constructed "right side" (vs. "inside" or "wrong side") out [there are also some significant differences in the structure of the photoreceptive cells (Figure 2) and many other anatomical features (Duke-Elder, 1958)]. This is hardly perplexing, Where its verted orientation is concerned, the octopus retina needs all the light intensity it can get—consider the animal's habitat! See also the "shadow-reflex" of these and other invertebrates (i.e., escape movements in reaction to changes in light intensity—vs. imagery—perceived as the harbinger of a predator). In these instances, then, the verted retina could be an arguable case for proper design, or as Dawkins would have it, the luck of the draw.
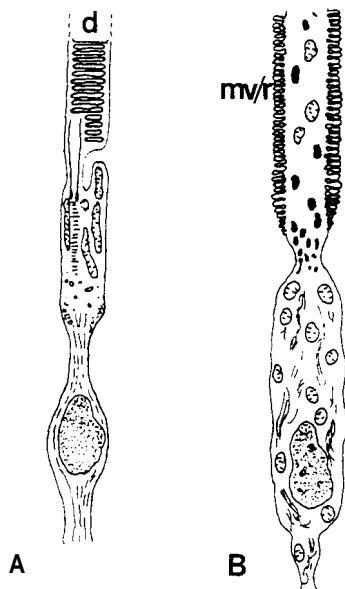

Figure 2. Photoreceptor cells. A rod cell, vertebrate retina. The photosensitive membranes are internal discs (d) packing the outer (apical) segment. B. Retinula cell, squid eye. The photosensitive elements are the microvilli (rhabdomere, mv/r). In both A and B, neural synapses are located at the opposite (basal) pole of the cells (not shown). After Eakin (1963) and Zonana (1961).

But is the inverted anatomy of the vertebrate retina supportive of Dawkins' thesis of accidental imperfection during its evolutionary development? Is it indeed "wrong side out'? Or is it an instance of designed specialization derived from a general theme? First of all, there is no evidence that the neural elements overlying the photoreceptors in the human eye are significantly diffractive, occlusive, or perturbing otherwise of the image (Hamilton, 1987). In this respect, the

vertebrate retina is no less "sensibly designed" (Dawkins, 1986, p. 85), engineering aesthetics (p. 93) notwithstanding, than any other. Where the "illogic" of a nexus between the pigmented epithelium and the photoreceptor elements is concerned for the human eye (Figure 3), Dawkins might be surprised to learn that this also occurs in the mollusk eyes he diagnoses as being assembled correctly (i. e., having the receptors facing the primary source of the light vs. back on the pigment layer) and in the eye structure of many other invertebrates (Figure 4) (Wolkins, 1958; Zonana, 1961; Eakin, 1963). Upon illumination, the pigment granules migrate within amoeboid cytoplasmic processes entwined among the photoreceptors (rhabdomeres), thus effectively screening scattered light, and return to the rearwardly (or in some cases laterally) placed cell body in the dark.
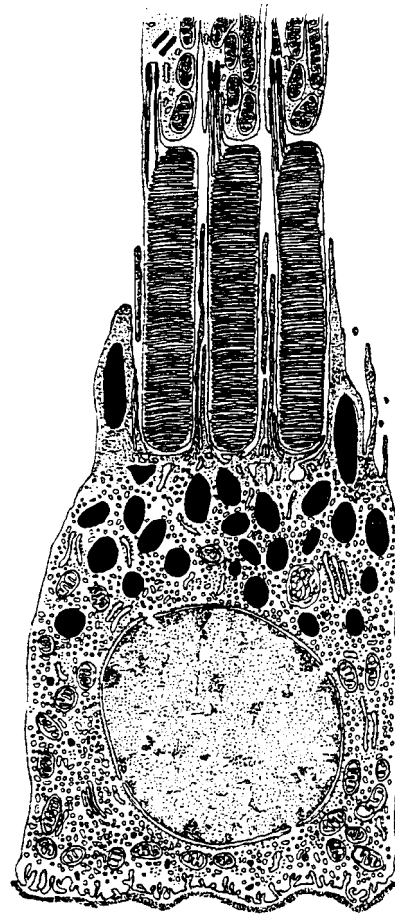

Figure 3. Mammalian retina illustrating the intercalation of the photoreceptor processes of three rod cells with a pigment epithelial cell. Appropriate to their physiological support of the photoreceptors, a high rate of metabolic activity by the pigment cells is indicated by the numerical density of mitochondria and wealth of other membraneous ultrastructure; this metabolic activity is sustained by the basally approximated (subjacent) choriocapillary network (not shown). Drawn from electron micrographs; see, e.g., Kristie (1979).

The functions pertaining to the allegedly "imperfect design" behind this interaction in the human eye are detailed by Bloom and Fawcett (1975). Besides those mentioned above is the shielding of the photoreceptive membranes from cytotoxic metabolites, turnover of
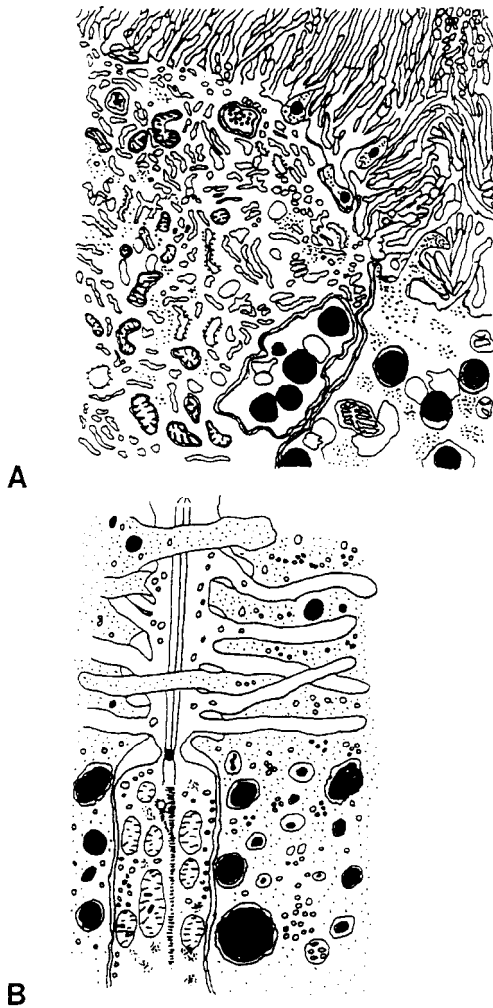
Figure 4. Invertebrate photoreceptor-pigment cell interaction. A. Longitudinal section through the distal tip of a photoreceptor cell (left) and adjacent pigment cell (right) in the molluscan retina; note pigment cell processes woven among the labyrinth of photoreceptor cell microvilli and apico-lateral surfaces of the photoreceptor cell body. B. Distal tip of a coelenterate photoreceptor cell, flanked by two pigment cells; note pigment cell interdigitating with photoreceptor microvilli. Drawn from electron micrographs; see Eakin (1963).

the outer rod segments (phagocytosis of shed discs), and the regeneration of rhodopsin. The latter most critical function occurs only if the photoreceptive processes maintain the intimate relationship with the pigment epithelium shown in Figure 3 [it is at this interface that clinically significant "retinal detachment," resulting in partial blindness, takes place]. If the rods and cones faced the incident light, the same relationship would have to obtain, but then the pigment layer would have to lie between the photoreceptive processes and the light; the photoreactive processes would thus be occluded by the opaque pigment epithelium! Meanwhile, were such a bizarre orientation to obtain, the pigment cells would lose in the process their necessarily intimate proximity to the physiologically supportive vascularization in the subjacent choroid [the importance of this feature is emphasized by the condition of diabetic blindness which results from impairment of this circulation].

I am reminded that in our lectures on the eye to freshman medical students, we begin with the sort of hyperbolic discourse Dawkins iterates to "bait" their interest, but then go on to show how, in fact, the inverted construction of the retina is not abstruse after all. It is altogether consistent with the physiology attendant this productively highly complex visual system *cf.* that of invertebrates. Dawkins should have stayed for the whole class!

That Oxford evolutionists could stand more training in cell biology (at least before writing on the subject) is further exemplified by Dawkins explanation for the maternal inheritance of human mitochondrial DNA—"Sperms are too small to contain mitochondria . . ." (p. 176). But there is no imperfection in design here either—these sperms do, in fact, contain mitochondria, and among the better developed mitochondria in existence are those that form the helicoidally arranged periaxonemal mitochondrial sheaths in human spermatozoa. The correct explanation is that the sperm tail, containing this mitochondrial structure (which supplies the chemical energy for its flagellar motility), is shed as the nucleated head enters the egg. Dawkins may be aware of that, but his discourse in this instance is fatuously misinformative. Along with Dawkins' obtuse account of the eye, is this another example of what Francisco Ayala, quoted in the publisher's bookcover review, exalts as ". . . the relevant zoological detail" on which "The . . . design of organisms and other apparent objections to Darwin's theory are met head on"? Or, as Isaac Asimov put it ". . . answering, at every point, the cavemen of creationism"? The devil remains in the details.

The fallacies in Dawkins' presentation generally have been reviewed elsewhere (Hamilton, 1987; Watson, 1988; Johnson, 1993), and addressed before the fact by Denton (1986) and Augros and Stanciu (1987), among others. Meanwhile, neither Paley nor Darwin could have had our appreciation of ultrastructure in the microworld; nor, apparently, does Dawkins. Besides the *faux pas* cite above, he avoids mention altogether of the example to be reviewed below [though its elucidation (Abrams et al., 1965; Cohen-Bazire and London, 1967; de Pamphilis and Adler, 1971 a, b) and subsequent additional descriptions had been in print—even in student textbooks—for sometime prior to the publication of Dawkins' 1986 treatise].

Bacterial Motility

From the presumption of biological diversity by descent with modification, prokaryotic organisms—exemplified in the present by bacteria—are considered evolutionarily primitive to eukaryotes. Thus, structure in bacteria would be expected to be relatively simple, antecedent to the complexity manifested in the protists, fungi, and the cells of plants and animals. Superficially, that anticipation holds. The prokaryotic cell's plasma membrane, for example, serves all of the functions the nuclear envelope, endoplasmic reticulum, Golgi apparatus, mitochondria and chloroplasts assume in eukaryotic cells, with few permanent morphological specializations. When it comes to specializations for cell movement, however, biologists were in for a surprise.

Some prokaryotes move over solid surfaces by a yet unclarified mechanism of gliding (Stanier et al., 1980)

reminiscent of gregarine protozoans (Maxwell, 1977). Hildebrand and Vinckier (1975) indicated that ectoplasmic annular myonemes (Pitelka, 1963) and cytoplasmic streaming are involved in the gliding of gregarines; the electron microscopy studies of Stebbings et al. (1974) identified pellicular microtubules as key elements in the process. However, typical of prokaryotes generally, comparable cytoskeletal elements (actin microfilaments, tubulin microtubules) do not appear to be present in gliding bacteria (vs. gregarines, which are eukaryotes). Spirochete bacteria effect a sinuous swimming motion which seems to involve bundles of filamentous structures running in the periplasmic space, i.e., that between the cell membrane and the cell wall (Bharier et al., 1971; Bermudes, Fracek et al., 1987).

Figure 6. Movement of the axoneme is accomplished by the sliding of the microtubular doublets past each other, which results from the alternate making and breaking of cross-bridges between them and the central microtubules. The relative displacement of microtubules during an "action stroke" is shown sequentially; A, the process "at rest"; B, beginning flexure; C, at maximum flexure, poised for the "recovery stroke." Refigured from Satir (1967).

Though Bermudes, Fracek et al. (1987) present data suggestive of a tubulin-like component, these filaments do not seem to be homologous to the ubiquitous microtubules of eukaryotic cell ultrastructure (Bharier et al., 1971; Bharier and Rittenberg, 1971). Otherwise, many bacteria possess motile flagella, but these are quite unlike the microtubular flagella/cilia of eukaryotic cells.

The mechanics of eukaryotic flagella are predicated on the structure of multiple soda-straw-like assemblies of *tubulin* subunits (forming microtubules per se) and ancillary linkage proteins (Goodenough and Heuser, 1985), collectively constituting the axoneme (Figure 5). A slide-and-catch mechanism of microtubular movement is believed to be the basis for its motility (Figure 6). Individually, microtubules average about 25 nm (nanometers, 10^{-9} meters) in diameter. The axoneme is about 200 nm in diameter. Otherwise, the size of eukaryotic flagella/cilia is variable from one cell type to another [such processes, when relatively large and singular to few in number are conventionally termed flagella; when smaller and numerous, they are referred to as cilia; the lesser used collective term is *undulipodia* per Margulis and Bermudes (1985)]. The axoneme arises from a microtubule-constructed basal body which serves as a nucleation center for the polymerization of tubulin subunits in the formation of flagella/cilia, comparable for the most part in structure and function to centrioles and their role in forming the mitotic spindle and microtubular arrangements otherwise (Karsenti and Maro, 1986).

A bacterial flagellum measures 10-20 nm in diameter and up to 10 μm (micrometers, 10^{-6} meters) in length. It is a single fiber formed of helically arranged subunits of protein *(flagellin)* molecules [altogether distinct biochemically and with no known relationship otherwise to eukaryotic tubulin], arising from a basal, granule-like structure anchored in the cell wall/cell membrane complex (Figure 7). Unlike the motile flagellum/cilium of eukaryotic cells (Figure 6), the bacterial flagellum
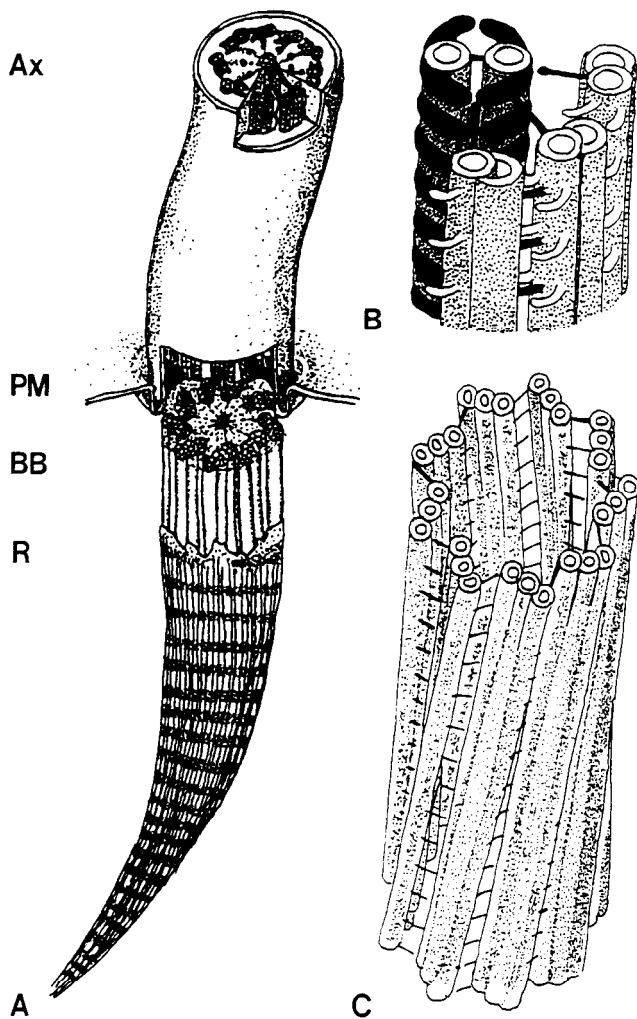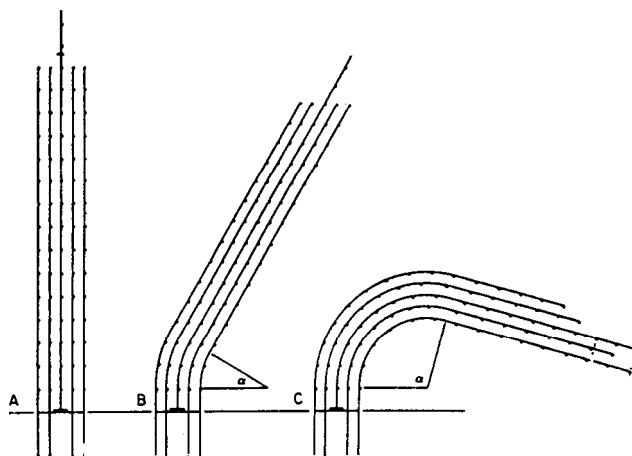

Figure 5. Eukaryotic cell flagellum. A. The motile axoneme (Ax) is composed of 9 peripheral doublet microtubules orbiting a central pair of singlet microtubules; these axonemal microtubules arise from the basal body (BB), composed primarily of 9 triplet microtubules; a structurally supportive fibrous rootlet (R) extends into the cytoplasm; PM, plasma membrane. Refigured from DuPraw (1968). B. Details of the axonemal microtubules; various proteins interconnect the doublet microtubules to one another and transiently cross link them to the pair of microtubules in the center. Energy is provided by the ATPase activity of *dynein,* a protein associated with the "ears" of the peripheral doublets. Refigured from Holtzman and Novikoff (1982). C. Interconnected triplet microtubules of the basal body. Refigured from Alberts et al. (1989).

does not bend, but *rotates* (Figure 7) about its long axis (at rates of 5-10 or more turns per second); collectively, the flagella generate sufficient torque to move the bacterium at speeds up to tens of μm per second. That velocity is impressive, considering that the bacterium is only one to a few μm long [when pondering bacterial structure, we have to think small!]. When the flagella are all rotating counterclockwise, they form a coherent bundle that pushes the bacterium in a straight trajectory; when the rotation is reversed (to clockwise), the flagella fan out causing the bacterium to tumble, and thereby change direction (Berg, 1975; Adler, 1976) (Figure 8).
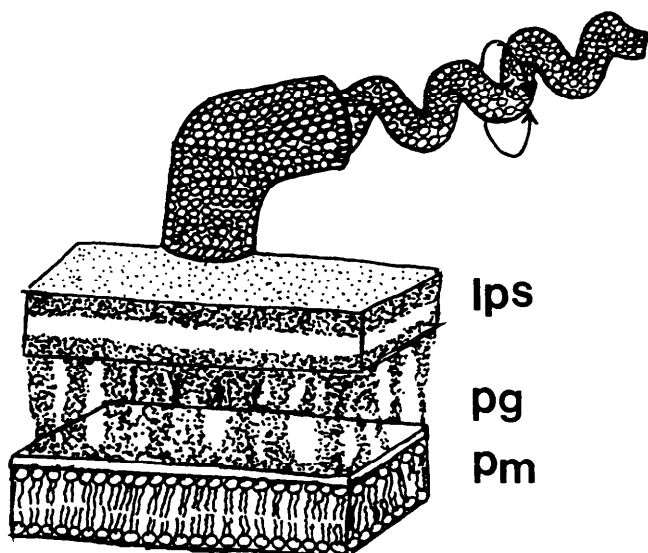

Figure 7. Bacterial flagellum arising from the cell wall/plasma membrane complex: the flagellum proper is a helical, relatively rigid structure that moves by rotation rather than bending, *cf.* **the eukaryotic cell flagellum (Figure 6); circular arrow denotes plane of flagellar rotation; lps, lipopolysacchride layer of cell wall; pg, peptidoglycan layer of cell wall; pm, plasma membrane.**

So equipped, bacteria are not only remarkably quick and agile, they are responsive to a number of ecologically significant stimuli. The conformations of a variety of proteins located in the cell wall and/or membrane are affected, e.g., by chemicals in the environment, light, and magnetic fields; signals are thereby generated which are translated to changes in rotational direction of the flagella (Adler, 1976). Specifically, it is a cascade of protein phosphorylations and, for long-term conditioning, methylations (Terwilliger and Koshland, 1984), that couples receptor activation (by chemical ligands, radiation, etc.) to rotational direction of the flagellar motor (below). Nutrients (e.g., sugars, amino acids) elicit a positive chemotaxis, while noxious (bacteriotoxic) chemicals (e.g., phenol) are repellants (Koshland, 1981; Russo and Koshland, 1985). Similarly, photosynthetic bacteria swim toward light of a wavelength appropriate to the function of their photosynthetic pigments, but reverse field on encountering potentially lethal ultraviolet radiation (Mason, 1991). Some bacteria *(e.g., Aquaspirillium magnetotacticum)* contain iron particles *(magnetite,* Fe_3O_4*)* within a sheath associated with the plasma membrane (Blakemore and Frankel,
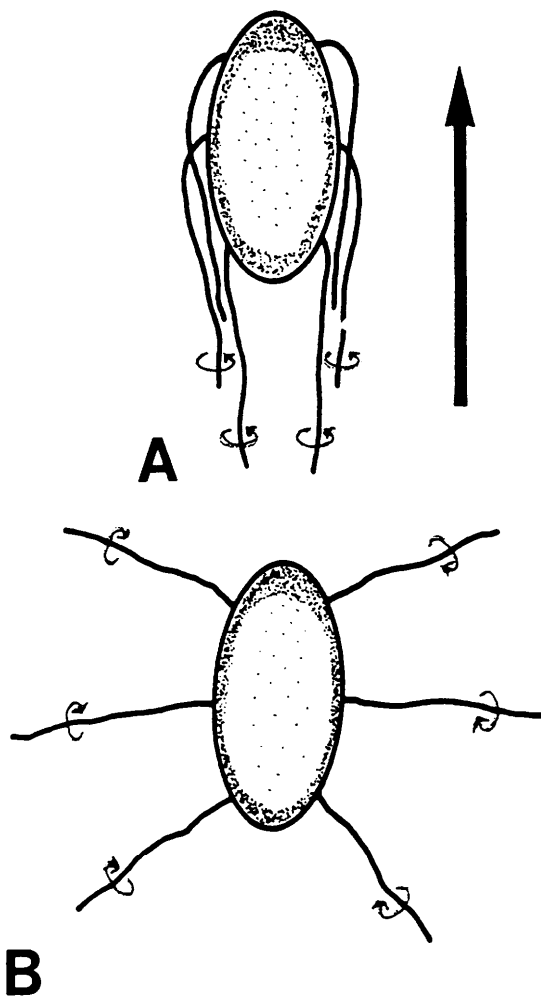

Figure 8. Bacterial swimming. A. When flagella are rotating counterclockwise, the bacterium is propelled in a straight line (in the direction of the arrow). B. Reversing the rotation to clockwise causes the flagella to splay out, resulting in a tumbling motion of the cell. After Berg (1975) and Becker (1986).

1981). Magnetic fields give an orientation to the particles which in turn directs the bacterium to move along the lines of force. This positive geotaxis guides the bacteria toward the optimum habitat—for this species in particular, which is microaerophilic, one with low oxygen tensions such as exist at the bottoms of bogs and marshes.

The Bacterial Flagellar Rotor

By far the most remarkable feature of the system is the rotor mechanism (Figure 9) that drives the flagellum. As biomechanics go, it is first of all the penultimate of miniaturization—equivalent in diameter to a single eukaryotic microtubule. As resolved by electron microscopy; it consists of a series of flanges, grooves, and wheels (yes, wheels!) mounted on an axle and turning on bearing surfaces with an efficiency that would be the pride of any industrial research and development operation. Indeed, such concerns as Stanley Electric's Hotani Molecular Dynamic Assembly Project (who could care less how the mechanism evolved or did not) are intensively researching its molecular structure and

properties. These include the ability to turn at speeds as high as 18,000 rpm, without lubricants (Koppel, 1991; Freedman, 1991) [A reduction principle in the "universal joint" translates this rate to the torque effective rotation, at slower speed, of the flagellum per se]. More than academic curiosity is driving Hotani's research; it is being funded at a level of about $2 million per year by Japan's Exploratory Research for Advanced Technology (ERATO) program.
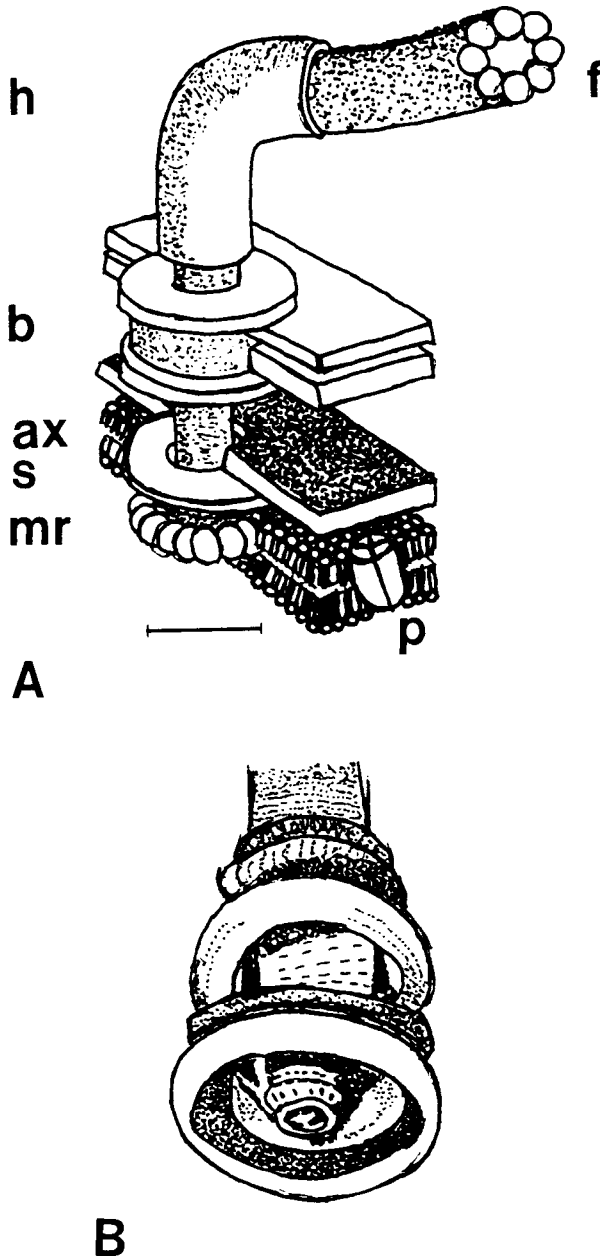
Figure 9. Motor-rotor complex of the bacterial flagellum. A. The basal-most element (motor ring, mr) is turned by electrical energy [from proton (H$^+$) flux across the plasma membrane] against a stationary ring (stator, s) embedded in the peptidoglycan layer of the cell wall, providing the torque transmitted to the axle (ax) and, in turn, the flagellar filament (f); p, proton transport site in the plasma membrane; b, bearing; h, connective hook ("universal joint"). Semischematic, after de Pamphillis and Adler (1971 a, b). Scale bar = 25 nm. B. Basal structure of the motor-rotor, drawn from a computer enhanced electron micrograph (Freedman, 1991).

The bacterial rotor mechanism is powered by electrical energy. Its basal-most wheel, inserted into the plasma membrane, operates just like the rotor of an induction motor in conjunction with a stator. The electrical current is derived from the flow of ions and attendant gradients across the membrane, most significant of which is the proton (H$^+$) gradient. This establishes what is referred to in cell physiology as the proton motive force (pmf, $\Delta\bar{\mu}_{H^+}$). The electrical work potential so generated is expressed as follows (Mitchell, 1961):

$$\Delta\bar{\mu}_{H^+} = \Delta\Psi - 2.3RT/zF\Delta pH,$$

where $\Delta\bar{\mu}_{H^+}$ is the pmf in millivolts (mv), $\Delta\Psi$ is the overall membrane electrical potential (in mv), R is the gas constant, T the temperature (Kelvin), z is the ion valence, F is Faraday's constant (coulomb/mol) and Δ pH is the differential chemical concentration of protons across the membrane (expressed as log $1/[H^+]$).

This parameter (pmf) has heretofore been implicated in the chemical work functions of oxidative phosphorylation and photosynthesis (Hinkle and McCarthy, 1978). Here, in the case of the bacterial flagellar apparatus electromotive potential is transduced directly to mechanical work, analogously to what intelligent R & D has produced in the electrical induction turbine—but one operating in the bacterium at an efficiency unheard of at General Electric.

The details of how the structural components interface with the electrical aspects of the system, accomplishing thereby the rotational force and direction of spin, are as yet unresolved. One idea is that the ions associate with the proteins at their insertion in the plasma membrane. Movement would be generated by repulsions/attractions between the electrical charges on the rotor ring and surrounding components. Alternatively (or coordinately) the ionic gradients might set off conformational changes in the proteins that propel the flagellum.

Like any design destined for wholesale manufacture, the structure of this molecular machine has a blueprint—in the genetic apparatus—which the bacterial cell follows in its construction. Indeed, molecular biologists are identifying the specific genes involved, isolating the protein products [there appear to be at least 10 in the motor structure per se, additional proteins comprising the proton channels, etc.], all in the effort to learn the details of their operation and attempt to replicate the system in various formats for technological applications (Freedman, 1991; Koppel, 1991; Stix, 1991). Overall, ultramicromechanics are becoming serious business. In 1991, U.S. investment in this type of research totaled $15 million, $30 million in Japan, and $75 million in Germany; funding of Japanese R & D in this area is expected to rise to $180 million over 10 years (Stix, 1991).

Evolutionary Considerations

Finally, consider the scale on which this marvelous apparatus has been developed. Its dimensions are measured in nanometers (billionths of a meter!) A group of M.I.T scientists recently got star billing in the pages of *Scientific American* for their construction of an electronically powered microwheel (Stix. 1992a). A similar project is underway at Case Western Reserve

University (Stix, 1992b). But this albeit extraordinarily clever bit of engineering is of *micrometric* dimensions—impressively small, to be sure, but some tens of thousands of times more bulky than "nature's own." Now, if we are to credit the intelligence at M.I.T. and Case Western for their devices (Figure 10), is it logical to discredit the possibility of intelligent origin for the bacterial rotor-flagellar complex simply because it is "natural"? Where it comes to creating a micromachine forceful enough to move another object, Bell Laboratories' Kaigham Gabriel observes (quoted by Stix, 1991, p. 168) that these man-made micromotors ". . . barely have enough power to get over their own frictional loads" [hence the limitations on their technical applications to date]. Getting real work from these machines is a target, not yet a reality. On the other hand, the bacterial nanomachine moves the organism up to 30 "body" lengths per second! Note, moreover, where this astonishing example of biological complexity, efficacy, and efficiency has been found—according to the evolutionary view, in cells putatively representative of the most primitive of life forms. In its operational principles, however, the bacterial rotor-flagellar apparatus is considerably more sophisticated than the flagella/cilia of "more highly evolved" eukaryotes the latter operate on linear mechano-leverage forces linked to conformational changes in proteins energized by ATP hydrolysis] which in their ratchet mechanics (Figure 6) are not much more sophisticated than a car jack. This of course is not to disparage the remarkable complexity of eukaryotic flagella/cilia in their own right, but to point out the the Creator has not respected phylogenetic hypotheses in terms of relative intricacy. One could argue at the outset, as do Bermudes et al. (1987), that where the ultrastructure of the flagellar process per se is concerned, the eukaryotic type is the more complex; however, when all structural and biophysical features are considered, I think the present view holds. Becker (1986) notes:

> Requiring, as it does, the structural equivalents of a rotor, stator, and rotary bearings, such a mechanism [for the bacterial flagellum] was originally considered unlikely, and [is] certainly without precedent in the biological world (p. 685).

Would God use His wisdom to confound the "wise"? The bacterial rotor-flagellar complex does not make a case for teleonomy (below).

Not surprisingly, evolutionists have yet to hazard any specific speculations on how the bacterial flagellar rotor complex might have arisen by the postulated mechanisms of chance mutation and natural selection. What physiochemical principle would prescribe the information for its structure spontaneously? While Margulis has proposed a model for the evolution of eukaryotic "undulipodia"—according to the serial endosymbiotic theory (Margulis and Bermudes, 1985; Bermudes et al., 1987)—and Cavalier-Smith (1982) has one predicated otherwise on endogenous mechanisms—direct filiation within the eukaryotic cell itself—no structure primordial to bacterial flagella as they exist in the present has been identified or suggested, imperfect or otherwise. It could be argued that with putatively billions of years at their disposal, bacteria could have evolved complex rotary flagella from rankly
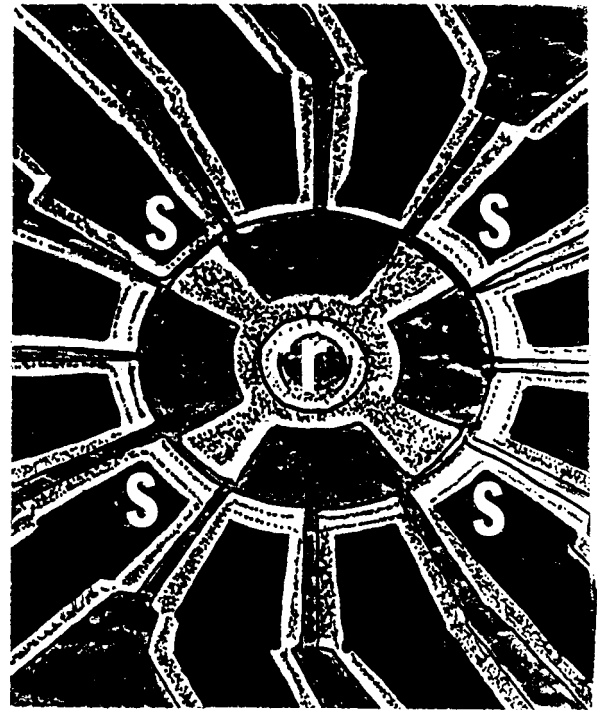

Figure 10. Man-made micromotor wheel. Voltage applied to four stator elements (s) aligns each of the four rotor blades with the respective stator poles; switching the voltage to the other poles causes the rotor (r) to spin. The rotor (including blades) is approximately 25 μm in diameter; the thickness is about 2 μm. From a photomicrograph (Stix, 1992b).

primitive ancestry, obliterating in the process of selection such imperfections the "panda principle" would predict. However, it is clear from the details of their operation that nothing about them works unless every one of their complexly fashioned and integrated components are in place. Gould's "panda principle" has no application here, at least in the evidence. Nor does the systematic distribution, taxonomically, of flagellated *cf.* non-flagellated bacteria correlate with any of the postulated phylogenetic relationships for the prokaryotes. And, so far as it has been ascertained, the structure/function of this device is virtually the same wherever it is manifested [There are some minor differences between rotor structure represented in gram-positive *cf.* gram-negative species noted by de Pamphilis and Adler (1971); not surprisingly, this correlates with the differences in cell wall structure that distinguish gram-positive and gram-negative forms in the first place]. Thus, if evolution is the answer to its origin, the bacterial flagellum had to have come into being by chance not just once but several times, independently, albeit by the same sequence of mutations and phenotypic consequences no less than 10 megadalton sized and precisely integrated protein components, etc.). And quickly, if credence is to be given the re-estimations of the time frame in which prokaryotic origin and diversity, evident in Archean sediments (Schopf, 1993), occurred (Overbeck and Fogelman, 1989). Then imagine the effects of natural selection on those organisms that fortuitously evolved the flagella and rotor mechanisms, torque-ing along at 18,000 rpm, but without the concomitant control mechanisms! Mechanisms coordinated, in terms

of positive selection pressure, with sensory receptors in tune with a myriad of environmental considerations specific for each of the myriad kinds of organisms possessing these flagella . . . as Kurt Vonnegut would remark, "so it goes." For a process which would be proved by imperfections, a lot is expected of evolution otherwise.

Augros and Stanciu (1987) perceptively diagnose teleonomy, the thrust of Dawkins' (1987) thesis, as:

> . . . linguistic subterfuge . . . invented to deny the evidence of purpose in natural things. Thus we are unable to see what nature is, and we imagine her to be many things she is not. This is the antithesis of good science (pp. 230-231).

[*Teleonomy* is a term which has been coined to denote the pseudo-purposeful functioning of biochemical systems; the *illusion* of design (Luria, 1973, p. 80)].

Meanwhile, researchers with better things to do than fantasize about evolutionary origins are learning, or attempting to learn, a great deal of practical science from the microworld, referring to the endeavor as *bionanotechnology.* Says Stanford chemist Steven Boxer, "Biomolecular systems have such fantastic properties in and of themselves . . . We've decided that since we can't beat them, we should join them" (quoted by Freedman, 1991, p. 1308). Becker (1986) writes (p. 684) ". . . we must credit nature with the *invention* of the wheel . . ." (emphasis added; see **Introduction).** Now, that is intellectually healthy humility. Pray that the next step would be a reverence for nature's Source.

Conclusion

As science would push back the frontiers of our ignorance, there remain archaic concepts (dating at least to 1859) of how things in the natural world have come to be that only a professorial Ph.D. could accept and blindly defend from the pulpit of pedagogy. So much for "blind watchmakers" and the theories they would contrive. See John 12:40 and 43, in reference to Romans 1:19-20.

Physicist-philosopher Paul Feyerabend asserts (Horgan, 1993, p. 36) that:

> Scientists develop and adhere to theories for what are ultimately subjective and even irrational reasons" and that modern scientists can be ". . . every bit the equal of ancient myth-tellers, troubadours and court jesters (p. 37).

Feyerabend, by the way, has defended in principle the attempts to have the creationist version of origins taught alongside the theory of evolution in public schools [though as far as I know, he is not a creationist himself]. In a 1987 treatise *Farewell to Reason* he warns against "tyranny of the mind," finding that "The best education consists in immunizing people against systematic attempts at education" (Horgan, 1993, p. 36).

Acknowledgements

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PANORAMA NOTE

Reprinted CRSQ Volume 16

Introduction

The *Creation Research Society Quarterly* has been published since 1964 (30 complete volumes). In an effort to make these volumes available, all of the missing issues have been reprinted. Brief synopses have been written on volumes 1-15 and have appeared in the previous 15 Quarterlies. In each synopsis, major articles are reviewed to give a person interested in scientific creationism a general idea of the contents of that volume. Many of the articles are of continuing interest and value.

Archaeology

John Schmich (1979, pp. 17-21) discussed the dispersion of man throughout Asia Minor after the Flood. Items included were topography after the Flood, slow and fast migration, agriculture after the Flood and headwaters of many of the post-Flood rivers. David Tyler (1979, pp. 47-58) wrote a comprehensive article on megaliths and neolithic man. He claimed that the evolutionary concepts of cultural development are inaccurate. Actually evidences of an advanced culture have been found. He presented all topics including Stonehenge within a Biblical framework of history. The rivers of Eden were the subject of a brief article (Bedigian, 1979, pp. 169-170,153). The rivers mentioned were the Batin, Karun, Tigris and Euphrates.

Astronomy

An interesting treatise employing electromagnetic fields was written by Akridge (1979a, pp. 68-72, 83) in defense of a mature creation at the beginning. The author (p. 68) noted that "As part of this mature electromagnetic field, light from the distant stars was created enroute from the star to the earth." Using classical Newtonian mechanics and general relativity, Akridge (1979b, p. 176-181,192) stated that the big bang model cannot be used to determine the age of the universe. He derived a modified Hubble's law and employed it to discuss quasar distances. All postulates were examined within a recent creation framework. The final article in this volume by the same physicist (Akridge, 1980, pp. 207-208, 196) concerned Jupiter's Galilean moons from the findings of the Voyager I space flight. It was suggested that volcanism on Io and the craters seen on the moons indicated a recent creation.

Biology

Anatomy

Phylogenetic development of sweat and mammary glands (Kaufmann, 1979, pp. 75-77) were compared from an evolutionary and a creationist viewpoint. It was explained that sweat glands are unique to mammals and that ". . . there is an up-and-down variation of complexity of sweat glands among the orders of mammals . . ." (p. 75). Mammary glands do not follow evolutionary phylogenetic predictions. The author