A Thrilling Chase: Nick Lane’s *Life Ascending*

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Nick Lane's book is terrific, a different presentation of evolution than we have generally had in the past. Lane, a biochemist, has chosen ten “Great Inventions of Evolution” to write about and to convey “some of my own thrill in the chase”. And thrilling each chase is. Lane brings his discipline's insights to the solution of problems that morphologic evolutionists, including paleontologists who have documented the history of life on earth, have struggled with for years. In examining those ten inventions, Lane demonstrates the tools, old and new, of evolutionary probing, and he lays out the key elements of these hypotheses with facts and strong inference.

Not everyone will agree with Lane's top ten, but he very carefully states his reasons for choosing these over other evolutionary developments. In any case, his ten are all critical, important evolutionary innovations in the history of life. If you don't agree with his ten inventions, note carefully how he deals with each of them, then apply some of the same reasoning to your own choices. His choices counter the views of creationists (including "intelligent design" proponents) without making a specific issue of them. He lets the science do that; hence the rebuttal is even more convincing.

Morphologists have hinted at solutions for many of Lane's top ten for a long time as well. Yet, the biochemical evidence—especially when integrated with evidence from a wide range of other fields, including cell biology, physiology, evolutionary biology, paleontology, geology, behavior, and molecular biology—makes for truly compelling reading.

Lane's writing is smooth and clear, unencumbered by fancy words or innumerable indirect objects and passive voice, and as a result is tremendously exciting. Some readers may struggle with some of the technical terms and phrases, but Lane generally explains all these very well. I could easily see what he was aiming for, and even for the parts with which I disagreed, the book was difficult to put down without thinking about the implications of his ideas for my own field and those of others. This is a book of well-developed hypotheses that may need further testing or even alternatives, but the informed reader will go away from it with a feeling not just of excitement but also with the creativity to make further and deeper inroads into these ten as well as other evolutionary innovations.

For each of his ten great inventions, Lane devotes a chapter of a little more than twenty-five pages. They fall into three groups. The first group of chapters—Origin of Life, DNA, Photosynthesis, Complex Cells, and Sex—considers the development of life from the chemicals of life through to fully operational eukaryotic cells. The second group—Movement, Sight,
and Hot Blood—deal with what might be called the eukaryotic or metazoan traits. The third group—Consciousness and Death—focuses on two things humans think about a lot.

Constructing and evolving a complex cell is complicated and involves many steps, but the enormous times available (millions of years) and biochemistry makes these steps almost inevitable. First, the biochemicals of life must come together. Lane thinks that this happened in the early hydrothermal vents along the ocean ridges, some 3.8+ billion years ago. Not only are the required elements present there, but also the geologic conditions near the hydrothermal vents supply an energy source, and the vesicles and tubules in the basalt and in the encrusted build-ups of minerals around the vents provide suitable containers for these elements to mix and to form into a cell of the same size. Not everyone would agree with this model for the origin of life, but it is a popular one based on finds of the last part of the twentieth century.

Other alternatives remain viable too. Darwin’s “warm little pond” full of the right chemicals and energy is still is favored by some. Tide pools, while not ponds, provide a reasonable model with a constant means of concentrating elements by tidal renewal and evaporation, with solar energy driving the reactions. Even on an early earth, probably millions of tide pools existed, where, over a few hundred thousand years, protocells and primitive cells could have emerged. Other possibilities exist too, but Lane tells us up front that we will read his views. And his view of the origin of life, whether right or wrong, stimulates more careful thought about other hypotheses, and hence is good science.

The DNA chapter, like all of them, starts with a vignette, this time of Watson and Crick debating and reworking their ideas in the Eagle Pub near Cambridge University. While these various stories are well known to many of us, they are written and connected to the following text in such intriguing ways that their retelling is not boring. They add to Lane’s story.

As for DNA, Lane admits that his ideas are far from conclusive because many parts of the tale remain to be understood completely. He is, however, satisfied that the main ideas are plausible, and the chemical reactions involved are well known. Those ideas and facts make an exciting hypothesis worthy of further testing.

The chapter on photosynthesis in part tells the story of why oxygen is so important for most of life as we know it and for Earth too as we know it. Without oxygen, we’d have a different world with a very different biota. Mars, for example, has very little oxygen, and no sign yet of life. It is one of these different worlds. Photosynthesis, of course, is the source of the oxygen in Earth’s atmosphere. The oxygen is generated in the process of stripping electrons from water molecules, and using those to form sugars from CO₂. Bacteria, algae and plants then use those sugars to manufacture more of their own cells. The photosynthetic process is enormously complex, but Lane enumerates the evolutionary steps as generally understood, including the final step, which involves a single mutation, making the process of oxygenic photosynthesis work.

By complex cell, Lane means a eukaryotic cell, differing in significant ways from bacterial or archaeal cells. In fact, eukaryote cells are a mix of those two genetically different prokaryotic cells and some others originating from early evolving cell types that shared among themselves many of their structures through gene exchange. For example, the mitochondria, necessary for generating the energy used in cells of eukaryotes, are prokary-
otes long ago incorporated into the early cells genetically and morphologically. How this happened is debatable, but the genetic signatures can be traced well back in deep time to those bacteria.

Still, this would not be a eukaryote cell—it needs a nucleus. The origin of the nucleus is also much debated, but Lane cuts through those debates to get at the biochemical necessity of having a nucleus with complex folds and holes in its membrane designed to protect genes from the protein-building ribosomes—simple and elegant, but not Darwinian. The complex cell evolved by the insertion somehow of one or more prokaryotes inside another one and the development of the nucleus—two accidents of early biology, Lane asserts. But such accidents may have occurred multiple times in the early prokaryote-dominated world, given the great amount of available time and propensity for gene exchanges in these groups.

Sex is commonly thought of as a feature of metazoans and higher-plants. However, it is actually a characteristic of eukaryotes in general. All eukaryotes, from simple single-celled forms to complete multicellular types such as humans, practice sex. Single-celled eukaryotes are commonly thought to be asexual, but that is simply not true. Most of them do divide asexually but at some point in their life cycles they undergo sexual reproduction. So why sex? Sex randomizes genes and produces variation, and it sorts bad from good mutations. From that variation springs all the differing kinds of eukaryotes. It is also what makes natural selection work so well among eukaryotes.

While movement seems to many to be chiefly a metazoan character, even single cells, for example Amoeba, move about in their search for food, for protection, for mating, and in response to conditions in their habitats. Lane acknowledges all of this, but his attention is chiefly on animals. Once animals develop locomotion, then active predation is possible, and that changes entire ecosystems. Lane, taking his lead from paleontology, thinks that these changes followed the Permo-Triassic mass extinction event, 251 million years ago. Prior to that, animals were more or less fixed on the substrate, so when very active motility evolved, it changed the biota for the rest of time.

All of this motility is generated biochemically by well-known processes, and it requires muscles, at least in animals. The muscles that do this can be traced back through animals to pre-bilaterians. For the rest of the eukaryotes that move, like the primitive slime molds, their intracellular motions are driven by the same two biochemicals as those in animal muscles—myosin binds with actin pulling itself along. These are the fundamental biochemicals whose gene sequences are 95% identical across all eukaryotes, differing only slightly here and there in their operations, according to Lane. How they operate in muscles and cells is different, and those differences are fascinating evolutionarily. Motility is clearly under strong selection.

As Lane points out, sight is a rare thing in the biological world. Even among animals, sight has evolved perhaps only six times, leaving the other thirty-two animal phyla totally blind. And the question of the evolution of sight, of course, resulted in the long battle over human eyes that creationists have waged with evolutionists: How could such a complex and unique structure evolve? “Easily” may not be the right word; perhaps “readily” is better, especially when vision is probably strongly selected. Indeed, vision of some sort has evolved
in algae, protozoans, starfish, bivalves, snails and cephalopods, in some kinds of “worms,” and of course in vertebrates, because sensing light is an advantage in the environments in which they live.

True eyes appear in the great Cambrian radiation and probably propelled it significantly, as the ability to see changed the way organisms dealt with one another and their surroundings. But, interestingly, all sight is dependent on the light-sensitive protein rhodopsin, and all “eyes,” whether they are complex human eyes or simple spots on single-celled algae, possess rhodopsin, as explained by Lane. And, again, the rhodopsin in all these organisms can be traced by gene sequencing from humans all the way back to algae in the early history of earth that used them to track the sun in order to photosynthesize more efficiently. The complexity of sight, then, resides not in the basic way it is done, but in the wide variety of ways to impinge light on the protein. Such inventions include simple sheets of rhodopsin, to pits with rhodopsin covering the internal surface so that shadows are detectable or the eye spots on the exposed mantle of several bivalves, to highly complex calcite lenses of trilobite compound eyes or of the similar lenses on the arms of brittle stars, to the unique organelles of some dinoflagellates that are eye-like structures within their single cells.

Many kinds of eyes exist among eukaryotes, and they evolved readily when rhodopsin could be used to sense light. Selection for light detection is strong, either in a general way to keep oriented to increasingly better vision for hunting or avoiding predators, as among metazoans. Sight is a predictable result of evolution. And the eye does not require an “intelligent designer”—it was developed by natural selection in a number of different ways.

In fact, the focus on human eyes in the creationist argument is fallacious indeed, for the human eye is not perfect at all. Indeed, the octopus eye seems to be constructed better because the neural wiring makes sense, whereas the human eye is wired backwards. The putative designer was not a very good engineer. Natural selection is not about perfection; it only has to produce structures that are good enough to provide a slight selective advantage. That’s why we have so many different eyes among the eukaryotes; any kind of eye is an advantage for those organisms that have them.

As Lane ascends from simple through complex cells to animals, “hot blood” becomes a driving force in evolution and Lane’s eighth great evolutionary invention. It’s been well debated, especially in dinosaur paleontology. Indeed, Lane capitalizes on that debate:

It’s a curious thing, but I’ve noticed there are few aspects of biology that we feel so chauvinistic about, we hot-bloods. The fury and spleen vented ... about whether dinosaurs, for example, were hot-blooded or cold-blooded is hard to understand rationally; it is a visceral distinction, perhaps something to do with our dignity, whether we would rather be eaten by giant lizards, or clever, scheming, fast-moving beasts, against whom we must pit our wits to survive. (p 206)

His passage evokes memories of Jurassic Park, and the popularity of that movie, seen by well over two billion people, certainly reinforces Lane’s opinions about how we think about dinosaurs, at least among little kids regardless of age. Lane goes on to explain that “hot blood” is not about temperature, but rather about stamina. Hot blood keeps animals going for longer times in their chases for prey, for mates, from predators, and so on.
The source of heat for these things can come from several sources, including a couple of internal ones, but internal heat generation comes at a large cost to the animal. Lane examines hot blood through a variety of avenues: physiology and anatomy of living animals, anatomy and inferred behavior of fossils, paleoenvironments, food preferences, atmospheric composition (that is, $O_2$, $CO_2$, and $CH_4$), and paleoclimates. Lane describes how all of these fit together in a general way to lead to hot blood, but a lot more remains to be understood about the history and the science of hot blood. The basics of the evolution are known, but this chase is not yet finished. It will be exciting to see how it too turns out.

Life Ascending ends with two evolutionary inventions that are particularly human. The first, consciousness, immediately brings religion into view. Lane notes that Pope John Paul II, although accepting evolution, still considered the human mind beyond the domain of science. Lane does not. He accepts that the mind is intimately connected with the brain, and that both evolved and therefore are subject to scientific analyses across many disciplines. Religion, Lane writes, is not what his book is about and he does not get into that in any detail. Yet he believes that the mind is so marvelous and majestic that it should be scientifically investigated, and also because it bears on the understanding of mental illnesses as well.

Consciousness is difficult to define, partly because all organisms can sense their environments—although only mammals and some birds seem to do it with self-awareness and with feelings (check with your dog about this). An autobiographical awareness and a sense of the future, especially death, separate humans from the rest of mammals. We are unique. That uniqueness, Lane writes, is no reason to set aside science, especially the evolutionary understanding of the brain and all that it entails for us. Lane admits that science does not know a great deal about it yet, and he even notes that this chapter is different from the other nine in that it does not provide a clear picture of how consciousness evolved. The brain and consciousness arose through natural selection, of that Lane is positive. His question then is, how, biochemically, does that work? As he says, no one can answer that question yet, but he shows how neuroscientists are approaching the problem. That makes for interesting reading and firms up the evolutionary view of how we came to be rather than the contrary view that it was all done for us by some supernatural being or force. Clearly, feelings and consciousness are electrical impulses somehow sensed and stored in the brain with various biochemicals. There is no soul.

Death is the tenth and last evolutionary invention on this trek through the ascendancy of life. It is a central fear humans have, and that fear has generated many myths that continue to obscure the science, at least for the general public. We have conceived of happy places we will go when we die if we conform to certain views in life, or of bad places if we do not conform to those views, or how we will return in yet another life, or as a ghost. We search for a way to extend life so we need not die, and we have paid dearly for it in energy (the legend of Ponce de León searching fruitlessly for the Fountain of Youth captures our imaginations for that very idea of longevity), money, technology (cryogenics), and religiosity. Yet we are stuck with a maximum life span of about 120 years, although very few humans come close to that.

Of course, an evolutionary reason set in our biochemistry is responsible. According to Lane, it is, again, about sex. We invest a lot in early sex, allowing many genetic diseases
to terrorize us in late life that are not subject to selection because they do not appear until after reproduction is finished. The story told by Lane is not yet complete either, but the chapter is rewarding in its examination of not just death but of ageing and later life and what we can do about it. Lane thinks we may not be able to increase our life span, but we can certainly increase our health span, if only medical science will fully embrace evolutionary biology.

And so Lane ends, noting in the Epilogue:

To doubt that life evolved … is to doubt the convergence of evidence, from molecules to men, from bacteria to planetary systems. It is to doubt the evidence of biology, and its concordance with physics and chemistry, geology and astronomy. It is to doubt the veracity of experiment and observation, to doubt the testing in reality. It is, in the end, to doubt reality. (p 287)

Well said.

Nick Lane's book is a rewarding read for anyone interested in evolution. Instructors of evolution will find a great deal in it to convey to their students, for it brings much to the field that we have generally omitted. It counters the unreal assumptions of those who doubt evolution by throwing nonsense and trivia at it. The book is a reading requirement for well-armed evolutionists who confront the myths and dogma of creationism and "intelligent design". Here are the answers in biochemistry, genetics, morphology, and other sciences to disarm those who doubt reality. For doubters, evolutionary biology, as shown by Lane, will require some careful reading, a little work at understanding, and a lesson or two in logic; probably few of them will accept that challenge. Our work in NCSE will go on until scientific literacy reaches everyone, and that too seems improbable, at least for the time being.

REFERENCES

ABOUT THE AUTHOR
Jere H Lipps studies geology, paleontology, and marine biology in order to understand the evolutionary history of life on earth and on other bodies in our solar system (Mars, Europa). His work has taken him to Antarctica and all the other continents to study fossil or marine animal and protist occurrences. Currently he is looking at the evolution of Neogene whales and the role of symbiosis in the evolution of reefs. He is a long-time member of NCSE and was presented with its Friend of Darwin Award in 1993. He is an emeritus professor at University of California, Berkeley, and a curator in the Museum of Paleontology there.

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