Nine

Killer Sunlight: The Land Animals

> I hold it to be true that pure thought can grasp reality, as the ancients dreamed.
>
> Albert Einstein

> What can be explained by the assumption of fewer things is vainly explained by the assumption of more things.
>
> William of Occam

The theory says that animals that avoided sunlight the most experienced less cancer and evolved the least. Earthworms, the bivalve mollusks and other light-avoiders are of lineages that did not undergo much transformation; all are relatively simple.

The logic, symmetry and power of the theory also tells us to look for the *most* transformed creatures in lineages with the longest histories of exposure to solar radiation. Ultra-violet light would have intensified cancer selection and caused more revolutions of the engine of transformation. Reality concurs with logic. The most transformed of all animals are those whose ancestors left the more sheltered marine environment to live on the sun-filled land surfaces of our planet. Because greater transformation usually led to increased complexity, the most complex of all living creatures are the surface-dwelling terrestrial animals and their marine descendants.

When judged by the number and variety of species the two most successful invaders of land were the insects (and other arthropods such as millipedes and spiders) and the vertebrates. But before explaining cancer selection's role in the evolution of those two enormous groups of strikingly different animals, I will comment briefly on two smaller groups of land animals, the mollusks and the annelids.

The common garden slug typifies land-based mollusks. That creature, a pest to gardeners, exhibits characteristics consistent with the heavy evolutionary influence of cancer selection. Although slugs crawl around without any shells or other obvious passive radiation protection devices, they crawl only at night. During daylight hours they hide beneath logs and other objects. That pattern of nocturnal exposure and daytime shelter is consistent with sunlight-induced cancer selection in the lineage.

Now let's consider *Oligochaeta,* the common earthworm. Like the transparent marine animals described in the last chapter, many earthworms are daily vertical migrators. They remain in their burrows during the day and crawl out only at night.

Oddly, the bodies of those night crawlers and other burrowing worms are *covered* with microscopically small eyes.

Why so many eyes? Vertebrates and insects, most of whom depend on acute vision for their very survival, manage quite well with just one pair of eyes. And among vertebrates that live underground, some, such as cave-dwelling fish and moles, have lost their vision; their eyes have atrophied. The disappearance of those fish and mole eyes is a stunning demonstration of how natural selection ought to work: change the environment so that the organ is no longer useful and the organ disappears.

So what about those earthworm eyes? No predators lurk underground. Visibility in burrows is near zero. If the eyes were there to detect any nocturnal surface predators the night-crawling worms might encounter, what could a slow-moving worm do to save itself if it saw a threatening animal? There are few phlegmatic predators. Predator-detection seems the unlikeliest explanation.

It seems, in fact, that if natural selection is our only analytical tool we

should conclude that earthworms ought not to have *any* eyes. But their bodies are *covered* with them. What in the name of Darwin is going on?

The eyes make sense, of course, if they were created in response to cancer selection. If the function of worms' eyes is to detect, not predators, but *light,* having them all over the body makes a great deal of sense. If compound eyes convert light to pain they would encourage the animals to avoid it. That, of course, is exactly what those relatively simple, small-brained creatures do.

(As I explain below, although they too can get cancer, fish that live in caves and mammals that live underground fear the sun less than annelids. The disappearance of their eyes is also consistent with my theory.)

Previous explanations for their subterranean habitat selection and nocturnal activity (such as predator avoidance) fail to account for the annelids' bizarre compound eyes. They also fail to note that an entirely different group of terrestrial invertebrates, the arthropods, contain many species that spend their adult lives exposed to sunlight.

When they emerged from the radiation-shielding protection of the sea the founding lineages of insects (and other terrestrial arthropods such as spiders, millipedes and land crabs) had to strengthen their bodies' cancer defenses. They had no choice. Water blocks radiation. The land surface is far more carcinogenic.

Insect gene pools collected an arsenal of weapons. The two scientists who discovered insect cancer, in larval *Drosophila*, Elisabeth Gateff and Howard A. Schneiderman, identified several characteristics that they thought might explain the relative rareness of cancer in insects:*

(1). Unlike humans and other vertebrates, adult insects have few cells

---

*

Gateff and Schneiderman did not, however, suggest that these characteristics came into existence as a result of cancer selection.

that divide. Cells that do not divide cannot possibly have cancerous offspring.

(2). Most insects undergo metamorphosis during development and during metamorphosis the adult animal is created from "imaginal disc" cells, not from the division of somatic cells that comprise larval tissue. Any tumors that might exist in the larval tissue could be discarded.

(3). Much insect growth occurs without cell division; the cells simply get bigger and, in some cases, DNA replicates inside the cell. Again, unless they divide, no cells, not even those in which a major mutational event has taken place, will have cancerous offspring.

(4). Insect DNA is spectacularly good at replication. When normal (noncancerous) vertebrate cells are kept alive in laboratory vessels, abnormalities appear in DNA after a few cell divisions. Then all the cells die as the result (it is safe to presume this) of the genetically-controlled aging process. Some *in vitro* human cells, for example, cease to divide after 50 generations.* In contrast, observed insect cells divide more than *1,500* times without abnormalities. If DNA inside insect cells is more efficient at mitosis than vertebrate DNA it will experience less cancer. (This leads to the question of *why* vertebrate DNA is not as good as the insects in cell division. I explain that later in the chapter.)

Gateff and Schneiderman do not mention other insect characteristics that I think were selected as cancer defenders:

Insects shield their larvae from sunlight. The larval stage is the riskiest because cell division is at its peak. They place larvae in loca-

---

*Human cancer cells can seemingly live forever in vitro. This shouldn't surprise us since it is their invincible capacity to divide that kills.

tions that afford heavy protection from sunlight exposure: underground, in mud nests, under the bark of trees, beneath rocks and inside hives.

Insects are short-lived. *Drosophila*, the geneticist's favorite experimental animal, goes from egg to egg in ten days. They do so because the insect genes adopted the "go and stop" defense.

Another sign of "go and stop" cancer defense is the insects' small size. Because cancer starts in a single cell animals made up of few cells are less likely to experience a catastrophic cancer-causing event than those with more cells.

Notable exceptions to the small sizes of insects are the queens of the colonial insects--bees, termites and ants. However, those relatively large (and long-lived--some queen termites live for twenty years) insects spend most of their lives in heavily sheltered habitats; termite queens and ant queens live underground, queen bees in hives.

It is worth noting how one old theorist "explains" the insects' small size. Stephen Jay Gould mentions (1977) not one, but two "reasons." According to that Harvard paleontologist, the insects' breathing apparatus is appropriate for small animals, but not big ones, therefore insects are small. His other "explanation" is the insects' need to molt. When they shed their exoskeletons, the insects' bodies are soft. Large soft bodies would collapse, therefore the insects have small bodies.

Gould is, of course, using circular reasoning: Why is the breathing mechanism suitable for small animals? Because the animals are small. But why are the animals small? Because of the breathing apparatus!

I don't know why Gould stopped with just two. He could have listed lots of other "reasons" for the insects' small size: their tiny legs, diminutive wings, lilliplutian digestive systems, wee brains, etc.

Gould's nonexplanations ignore the cancer-defensive features mentioned by Gateff and Schneiderman. He also doesn't explain the insects' short lives. He fails to recognize that insects have a panoply of mecha-

nisms that reduce the possibility of cancer death through the simple, but highly effective means of sharply curtailing somatic cell production.

But if insects are tiny because they can get cancer why are humans and other vertebrates, all of which experience more cancer than insects, so much larger?

That's a good question. It gets a good answer.

The first terrestrial vertebrates, the ancestors of the largest and most complex land animals, left the sea armed with a unique anti-cancer weapon. This was something substantively different from the devices used by insects, or annelids, or mollusks. What those first terrestrial vertebrates had was a *second* line of defense against cancer, an array of mechanisms that (unlike cell-curtailment or sunlight-avoidance, which work by preventing the *initiation* of cancer) could kill cells *after* they became malignant. Those animals had a powerful *immunological system*.

The idea that a major function of the immune system, perhaps *the* major function, is to protect against cancer is not new. Robert A. Good and Joanne Finstad, for example, suggested in 1968 that "A primary *raison d'être* for the lymphoid system and certain immunities is surveillance against [cancer]." More recently, the catastrophe of AIDS, a virus-caused disorder that impairs the immune system, has provided strong empirical evidence of the system's vital role in fighting cancer. Many AIDS victims die of it. Other compelling evidence is the effort now underway in many major cancer centers, including the National Cancer Institute, to artificially enhance the immune system's ability to kill cancer cells. Researchers wouldn't undertake those programs unless they were convinced it already kills cancer cells.

All those facts support two related ideas of great importance to understanding vertebrate evolution:

> Cancer *initiation* is a routine occurrence in vertebrates, the only animals known to have cancer-specific immune systems.

> Surveillance and elimination of routine malignancies is a major function of the immune system.

Vertebrates had an *active* secondary defense against cancer. The evolutionary significance of the fact that it could only act against cells that were *already* cancerous is enormous. It cannot be exaggerated. The invertebrate lineages, which depended on single-phase passive defenses, did produce complex animals living in sunny habitats but the animals are either small and short-lived like insects or they are encumbered with heavy armor plate like land crabs. Other invertebrate terrestrial lineages produced simple animals like earthworms and garden slugs that hide from sunlight. But only the vertebrate lineages produced complex *and* large terrestrials, and, contrary to conventional interpretations, their back bones were not responsible. Immune systems and cancer did it.

Lots of cancer. The immunological system could not have emerged *unless* primary cancer defenses failed--repeatedly--to protect the animals. Evolutionary logic informs us that intense cancer selection was needed for complex cancer-specific immune systems to originate and to evolve to their present level of efficiency and complexity.

To get some sense of that complexity, consider the thymus. That gland, which is found in all vertebrates, attains its greatest size relative to the human body during the prenatal and neonatal periods. During that time it produces substances that activate certain genes inside lymphocytes, the killer cells that hunt down malignant cells and other antigens during the lifetime of the organism. After indoctrinating the body's T-cells--a process completed, in humans, about six months after birth--the thymus is turned off. It atrophies and eventually disappears; removal of the gland in adults does no harm. But without that good-for-a-lifetime processing of T-cells during infancy those cells could not function as cancer killers.

This is mind-boggling complexity. It's impossible to even imagine a man-made analog. The best I can do is a computer-driven police academy that not only teaches each cop how to identify and eliminate various threats to society but ensures that each cop's descendants, for millions of unborn generations, will also have that knowledge!

There can be no natural explanation for the origin of this cancer-fighting wonder other than past heavy losses of juveniles to cancer.*

Because it was activated only after healthy cells were converted into the deadly cancer state, the increasingly efficient immune system enabled many species to weaken, or even abandon, first line defenses. The animals were still, from the gene's view, disposable vehicles, and every act of somatic cell creation in a developing animal was still a threat to the germ line. But the "fail safe" nature of immune systems liberated the gene pools. Released from the restrictions imposed by risk-aversive cancer defenses, many of these emboldened invaders of the sun-drenched land surfaces could do what would be unthinkable with only a single line of defenses:

Increase the length of prereproductive life.

Lengthen total life spans. The aging process was attenuated.

Invest more cells in each organism. Giant animals--dinosaurs at an earlier time, humans now--came to dominate life on earth.

Externalize soft tissue as the need for noncellular external hard coverings were reduced or eliminated.**

Because of that externalization of tissue, develop greater flexibility

---

*The immune system also fights viruses, bacteria and other threats to the germ line; many juveniles were killed by those pathogens. But these facts have no effect on the validity of my assertions about cancer selection's evolutionary role.

**Perceptual errors mislead us. Biologists usually refer to this phenomenon as the internalization of the skeleton. It is more enlightening, however, now that we know about oncogenes, to view this particular transformation as the emergence of soft tissue (made up of dividing cells) from behind protective coverings.

and mobility.

Eliminate, in some species, body hair, a noncellular covering with proven cancer-defense properties. (I say more about hair later in the chapter.)

Reduce skin pigmentation in many humans and in a few species of domestic animals--some pigs and some rabbits have white-pink skin.*

In many species, spend entire days in direct sunlight.

In most immunologically-equipped lineages the animals increased in size. That is because immune systems not only *permitted* larger animals, they *encouraged* them. With an effective immune defense in place additional cells actually protect against cancer.

But if *fewer* cells were cancer defensive in insects, how could *more* cells be cancer defensive in vertebrates? To understand this apparent paradox, consider two vertebrates with cells of similar size. One is a mouse whose liver is no larger than the eraser at the end of a pencil. The other is a whale, and it's liver is the size of a small automobile. If cancer were to start in one liver cell in each animal and proliferate at the same rate of speed, which animal would be the first to die? Obviously, the mouse would go first. Because of its smaller size, the mouse's liver would stop functioning before the whale's.** And the whale's immune system, with more time to organize a counterattack against the killer cells, would have a better chance of winning its fight against the killer cells and might

---

*Even the reduction of pigmentation may have been caused by cancer selection. Recent research suggests that human breast cancer among Caucasian women is lower in sunny locations than in darker places. The researchers' hypothesis: Vitamin D, which is more easily absorbed by light skin, acts as a cancer defense.

**Their small size makes mice attractive laboratory animals (easy to handle, cheap to maintain, etc.) but it may also explain their seemingly higher sensitivity to cancer. The "carcinogen of the month" phenomenon would probably disappear if researchers worked with larger animals.

save the animal.

(In his "Phylogeny and Oncogeny" Clyde J. Dawe pointed out that although whales have many more cells at risk than mice and might be expected to have higher lethal cancer rates they in fact have far lower rates. He speculated that certain physical characteristics of whales [he mentions higher levels of fatty tissue] might explain the whale's lower death rate. He seems not to have considered time-to-kill versus time-to-react as a factor.)

The terrestrial vertebrates include among their number the only *large* animals that regularly expose themselves to intense sunlight. Vertebrates are also the only animals known to have cancer-specific immune systems. And they have yet another unique characteristic: they are the only animals that sleep.

Sleep is a major evolutionary mystery.* Land vertebrates spend one-third of their lives in an unconscious state, utterly defenseless against attack by predators. Natural selection would have worked against the selection of this defenseless state unless it offered other life-or-death benefits. My theory looks at all the facts and asserts that sleep's primary function is to defend against cancer.

To begin my case, consider that the greatest risk of cancer initiation occurs during mitosis. That delicate process of passing genetic material from one mother cell to two daughter cells is, in organisms with oncogenes, nothing less than death-defying. It is also an incredibly frequent occurrence in large animals. Cells divide ten quadrillion times during a human lifetime. *That's 350 thousand million cell divisions every twenty-four hours!* If just *one* of those divisions went awry, the mishap could kill the organism. And any cell divisions that misfired in juveniles would imperil the lineage.

---

*This is another problem that professional evolutionists seem to duck. Although the authors of some books about sleep speculate about its possible evolutionary function, I have yet to see it mentioned in an evolution text.

Significantly, these highly dangerous acts occur in vertebrates *during sleep*. Human skin cells, for example, divide mostly between the hours of midnight and 4 AM. The connection with sunlight is obvious. Cells divide at night in animals that are active during daylight and during the day in most nocturnal animals. Bats and mice sleep during the day, but they sleep, and their cells divide (its been observed and measured in mice) in places sheltered from sunlight; bats sleep in caves and mice in burrows.

Using the "cause of death" rule, the universality of sleep in land vertebrates (all mammals, birds and reptiles sleep) leads to the question, what killed animals that did *not* sleep? The facts--mitosis during sleep, sunlight avoidance while sleeping--point to cancer.

Another set of facts that supports this idea is the age-related sleep pattern in our own species. Humans sleep most during infancy--newborns sleep 18 or more hours a day--when new cell production, and the risk of cancer initiation, is at its highest level. After infancy sleep decreases steadily with age, but with one significant exception. Adolescents sleep more than pre-adolescents. Again, there is a correlation with growth and increased cell division: rates of increase in height and weight during adolescence are second only to infancy. Cancer experience also correlates. Adolescents are especially vulnerable to cancer related to growth. Leg bones grow rapidly during adolescence and cancer in those bones almost exclusively occurs in teenagers.

Another medical fact pointing toward sleep's function as a cancer defense: the increase in sleep following severe trauma. Persons recovering from major surgery or other trauma--when cells division increases to repair damaged tissue--sleep more than normal.

There is still more evidence. The pituitary gland secretes growth hormone when we sleep. According to Yasuro Takahashi, "...the highest peak of [growth hormone] concentrations in a 24-hour period always occurs during...sleep."

How does sleep enhance cancer-free cell division? I don't know. This is a black box proposal. I suspect, however, that the state of unconsciousness was selected to enforce physical inactivity and that inactivity provides an internal somatic environment conducive to the successful

division of cells.

I have said that insects shield their larvae from solar radiation as a cancer defense. The terrestrial vertebrates also protected their embryos from radiation, but they didn't put them under rocks.

Most vertebrate fish embryos were not protected by their parents. They reproduced with external fertilization and external gestation; many fertilized eggs develop in open water. But when some of the fishes' descendants migrated to land they moved toward greater embryo protection. This is evident in the earliest land animals, the amphibians. Although some amphibians use the fish system of external fertilization and external gestation, others use internal fertilization followed by external gestation. And a few species use both internal fertilization and internal gestation.

In the next big evolutionary step, the emergence of true terrestrials, the reptiles and birds, fertilization became internal and all embryos were protected in hard-shelled eggs, some of which were buried by the parents.

Embryo protection was further intensified in mammals. Both fertilization and gestation are internal.

That progression from exposed fertilization and exposed gestation to shielded fertilization and shielded gestation implies unrelenting selection pressure. Such long term trends in many lineages are best explained, again applying Occam's Razor, by a single selection mechanism working throughout the long transformation period, rather than by a melange of assumptions.

Increased protection of embryos occurred in lineages that underwent great transformation and my theory says transformation itself could not occur without lots of juvenile cancer, including embryo cancer. The intensification of cancer selection pressure as the animals moved away from the protection of the sea would also explain the change to internal fertilization and internal gestation.

As my theory would predict, no comparable intensification of protection of very young offspring occurred when *plants* moved from

marine to terrestrial habitats.

Despite the fact that many mammals have discarded heavy external protection against sunlight, all land vertebrates continue to shield mitotic cells from natural radiation.

Blood cells in humans and other vertebrates, which divide more rapidly than other cells, divide inside large bones. As X-ray images demonstrate, bone tissue protects against radiation.

In four-legged animals, the soft organs, which are made up mainly of dividing cells, are protected from exposure to sunlight by layers of cells that do not divide; muscles and, to a lesser extent, nerve cells.

The observation that pre-mitotic cells are routinely shielded by cells that do not divide suggests that cancer selection explains one of the great mysteries of recent evolution, the origin of the human brain.

Paleontologists have established, with the 1974 discovery in Ethiopia of the hominid fossil "Lucy," that our ancestors first became bipedal about 3.5 million years ago. They stood up before they acquired their large brains. The big brains--they more than doubled in size from Lucy's--did not appear until about 2 million years ago. That sudden appearance--and in evolution 1.5 million years is a short time--is a puzzle. So quickly did the new brain appear that biologist Anthony Smith estimates that it grew at an average rate of 90,000 cells in each generation!

All previous ideas about that sudden origin revolve around the supposed survival value of human intelligence. They ignore several powerful signs pointing to cancer selection.

The *locale* where our ancestors were living when the big brains first appeared is highly significant. It was in the Rift Valley, which runs from North to South, dividing central Africa in half. West of the valley the land is covered with heavy foliage; it's mostly deep, dark jungle. To the east it's savanna; open land bombarded by fierce tropical sunlight. The valley itself, where Lucy lived, is now one of the hottest places on earth. It is risky to assume that current climatic conditions obtained millions of years in the past, but I make no such assumption. According to a 1984 article

in *The New York Times*, specialists are convinced that humans appeared when the area changed from shady forest to sun-drenched savanna.

Suddenly spending entire days with the blazing African sun beating down on the top of their heads (thanks to their recent adaptation of bipedalism), early humans suffered losses from brain cancer. But--and this is essential--most brain tumors do not start in functioning brain cells, not in neurons. They start in glial cells, dividing non-nerve cells that circulate inside the cranial vault. Neurons are postmitotic; they never divide, not once the brain has been constructed. And brain construction is completed in *early* childhood.

If glial-cell cancer killed many human children, selection would have favored the placement of additional neurons on the top of the mammalian brain we inherited from Lucy and our other protohuman ancestors. Those additional nondividing cells, placed between the dividing cells and that harsh African sun, would have blocked the carcinogenic solar radiation.

Certain observations support this idea:

Cancer is the second leading cause of death among American children. And the *second* leading site of lethal cancer in children is brain cancer; it accounted for 14% of childhood cancer deaths in a recent year. (The leading cause of death is accidents and leukemia is the most common cancer.)

Children have thick hair *only* on the top of their heads. Humans lost their thick *body* hair, and biologists are convinced that they shed it to survive in the heat of the African plain. But most of our body heat escapes through our heads. (It's why most people wear hats in cold weather.) If we got rid of body hair to keep cool in the African heat, its retention by juveniles (remember, their welfare was essential to lineage survival) in the one place where it would most interfere with body-cooling suggests that something else was also involved. I think childrens' hair protected them against sunlight-caused brain cancer. Hair's ability to defend against cancer has been established in experiments. Nude mice (they're shaved daily) exposed to ultraviolet radia-

tion displayed increased tumor formation.

> Our big brain's intellectual capacity is far in excess of what was needed to survive. Even Alfred Wallace, its codiscoverer, was convinced that natural selection could not explain the human brain. He argued that natural selection would produce the sufficient, but not the supererogatory. Wallace was right.* There is no conceivable survival purpose for a brain capable of knowing how to play bridge, write symphonies or create new theories of evolution.

But our genes nonetheless did amass a lot of additional non-dividing neurons on top of Lucy's mammalian brain. Using the "cause of death" rule, we must ask how did those creatures without the new mass of brain tissue actually die? What killed them?

There is, of course, only one answer consistent with all the facts: they died of brain cancer starting in those non-neural glial cells inside the cranium.

Although the increased intelligence provided by the enlarged human brain undoubtedly helped our ancestors to survive, any *successful* theory of the human brain's origin should explain why it appeared when it did--soon after hominids stood up--and what killed young animals who were not equipped with the new improved organ.**

The idea that cancer selection caused the origin of the human brain may strike some as overly audacious. But it is based on the only idea in this book--that non-dividing cells protect dividing cells from cancer--that

---

*He was right, that is, about the inadequacy of the natural selection explanation. He was wrong to attribute our brain's origin to supernatural causes.

**The selection of a character for one function (cancer protection) and its subsequent use for another beneficial purpose (problem solving) is called preadaptation. It is an established element of neo-Darwinism.

It is also possible that bipedalism caused other increases in cancer. I am not aware of any studies comparing the incidence of human breast cancer or cancers originating in the abdomen with comparable data for larger tetrapods. The latter animals afford (by virtue of their horizontal configuration) their mammary glands and soft internal organs more protection from sunlight than do humans and may, as a result, incur less cancer at those sites.

can be tested experimentally. I have designed a simple experiment for that purpose and describe it in Chapter Eleven.

The terrestrials are the most transformed of all animals because their lineages endured more cancer selection than any others. The engine of transformation ran faster and produced greatly changed animals.

One way to demonstrate how transformational evolution accelerated in the harshly carcinogenic terrestrial habitat is to compare a large terrestrial mammal to an animal that never left the marine environment.

At one of the two scientific meetings I have attended, a renowned biologist remarked, in the midst of a wide-ranging lecture, and for reasons best known to him, that cows were no more complex than sharks. That professional scientist did not, I am sure, actually mean to select a specimen of domesticated cattle, or--adding sin to error--to single out the female of one species to make his point. Domesticated animals are off-limits to those of us active in evolution for the obvious reason that they were artificially bred to have characteristics that made it easier for humans to dominate them. A comparison of cows with sharks is particularly unhelpful because cows were bred to be both docile and stupid. It would be fair, however, to compare a *wild* bovine to a shark to see if the big land animal is any more complex than the big marine animal. I will do just that, using the African Cape Buffalo as my example.

According to Dorst and Dandelot's *A Field Guide to the Larger Mammals of Africa*, these massive bovines (they can reach more than five feet in height at the shoulder), are known to move in massive herds of up to 2000 individuals. The great mass of animals is dominated by a master bull and (no sexists, these beasts) a senior cow. Those co-generals of what amounts to an army of buffalo depend on scouts--other buffalo that fan out from the main body of the herd--to warn them of approaching danger. This is truly remarkable behavior. Could our earliest human ancestors have done any better when moving through hostile territory?

In addition to that extraordinary organized group behavior, which suggests a level of intelligence far above that of sharks, the African Cape

Buffalo has a reputation for savagery. Not only do hunters consider them the most dangerous of all African game, these beasts, unlike most African grazing animals, do not flee from approaching lions. Instead, when the big cats approach the herd the adults gather around the young calves and face the lions, fully prepared to gore any attacker. The lions usually slink away. Of course, diseased buffalo and even youngsters occasionally succumb to predators, but unlike old Bossy in the barn, these wild bovines fight ferociously when attacked.

Sharks are also ferocious, but their savagery is quite another matter. They're carnivores and their daily survival depends completely on their ability to violently overwhelm and then kill other marine animals in order to eat them. Shark violence is simply a genetically-determined means of obtaining food. Cape Buffalos, however, are herbivores; they don't kill to eat. And because their ability to fight when attacked is not related to the need for nourishment, its evolution involved additional transformation. In their lineage two separate complex systems evolved, one to gather food in a peaceful manner and another to wreak violence on would-be predators. Sharks needed only one system. (Although there are fish who graze and fish who attack other fish, I know of no fish species that survives on plant matter and whose members routinely kill big predators.)

The shark is nonetheless a complex animal and, as I have been saying, the old theory of evolution cannot explain *any* complex animals including sharks. But theories of evolution are supposed to explain *transformation*--the creation of complexity--as well as complexity itself and in comparing the history of sharks with bovines it is clear that there was a lot more transformation in bovine lineages than in the sharks'.

The shark phylum is very old. According to the fossil record the earliest sharks appeared about 350 million years ago. Since that time sharks have evolved somewhat, having produced about 200 species of sharks and 300 species of rays. But sharks and rays are still sharks and rays. Sharks may be fascinating (and terrifying) predators, but that's all their lineages have been able to produce. For that reason most biologists consider them evolutionary dead ends.

But if we examine the lineage of the African Cape Buffalo over the

same period we will find a profoundly different history, for when the first sharks came into existence they may have encountered the buffalos' ancestors. They were vertebrate fish.

So great was the transformation in the fish-to-buffalo lineage that it would be impossible to list all the physiological changes that occurred, but it is apparent that it first required the emergence of amphibian capability, then reptilian characteristics, and still later, mammalian characteristics. There was a switch in reproduction from the fertilization of eggs in the open sea to internal fertilization and then to internal gestation, the change from cold-bloodedness to warm-bloodedness, a drastic change in digestive systems in order to survive on rough plant matter--etcetera, etcetera, etcetera. All those gross transformations required radical changes in development programs and processes and in the constitution of individual cells.

It ought to be clear by now that it was foolish of that famous biologist to utter his strange comparison of the complexity (which is to say, the evolutionary history) of sharks to that of bovines, or, for that matter, to any of the numerous land descendants of vertebrate fish.

The evolutionary changes needed to produce land vertebrates simply could not have occurred without greater losses to cancer selection than those endured by the virtually unchanged shark lineages. And since my theory says that the operation of the engine of transformation meant that increases in complexity caused increases in cancer selection, it should come as no surprise that its corollary--less change in the animals meant less cancer selection in the lineage--is borne out by modern sharks. Genes that have been producing nothing but sharks (and shark-like rays) for 350 million years have the learning curve of self-manufacture well behind them. That is the evolutionary reason why modern sharks have little cancer; their cancer defenses have not been challenged by changes in development programs to the extent experienced by terrestrial vertebrates.

Theories whose predictive ability holds up under extreme conditions are superior to those that falter.

If sunlight-initiated cancer selection transformed simple animals to complex animals what happened if lineages were *totally* deprived of sunlight for many millions of years? There are such lineages and the animals they produced support my theory--in their own peculiar way.

No terrestrial animals avoid sunlight more thoroughly than those that live *inside* other organisms. Internal parasites like the common tape worm haven't seen sunlight for several hundred million years. And, of great theoretical significance, these parasites have done something evolutionarily extraordinary. They have *lost* complexity! One authority [Huff] says tape worms "lost practically all trace of free-living characteristics," that they have no digestive system and resemble "a colonial form in consisting of many, fairly autonomous parts."

These extreme sunlight-avoiders resemble colonial organisms in another way. In at least certain species they are capable of exceptional longevity; tape worms that inhabit human guts can live for 35 years. Large simple organisms that live for a long time--trees, sponges, certain cnidarians--are prevalent in nonanimal lineages. But simplicity and longevity in the same animal is unknown--except for these internal parasites.

Again, cancer selection explains. Cancer defenses enabled DNA to create complex organisms but in tapeworm lineages, prolonged relief from the pressure of cancer selection (by depending on the defenses outside themselves, in the body of the host animal) weakened the internal cancer defenses and lowered the tape worm DNA's capacity for precise development. The worms regressed to tissue-level simplicity.

By regressing tape worms indirectly confirm my central idea that exposure to cancer-causing sunlight caused complexity.

Some readers may feel overwhelmed by my insistence that so many separate characters and traits of land animals were cancer-related in origin. They may think I go too far. But the most spectacular accomplishment in those lineages, especially those of insects and vertebrates, was not the accumulation of this feature or that character. It was the sheer breath-

taking magnitude of transformational evolution itself. From the time they left the sea, surviving terrestrial animal gene pools--spectacularly efficient directors of animal-manufacturing systems--added an immense number of somatic revisions to *already* complex organisms, and they did it without once breaking the chain of successful replication in breeders. Anyone who thinks that could possibly have happened without intense selection pressure from cancer should reflect upon the arguments made in earlier chapters. Rather than overdoing it, I have probably missed many manifestations of that pressure.