The making of the cat essay

IN THE VERY BEGINNING, about 4. 6 billion years ago (give or take a few years), a small ball of rock, water and gas had come to be and immedi- ately set about the process of combining its atoms into more and more complex arrangements. Thus began that most wondrous story, the evolu- tion of life on Earth.

For the first 2. 1 billion years of the Earth's existence, the Archeo- zoic Era, life very slowly evolved. The Earth's crust was still in flux and covered for the most part by shallow seas. The atmosphere was composed primarily of methane, ammonia, carbon dioxide and water vapor. From these primitive chemicals life evolved. There are two primary schools of thought on the processes involved: the " soup" theory and the " sandwich" theory.

According to the more-popular soup theory, chemical evolution first took place in the upper atmosphere, where ultraviolet radiation from the sun could generate an assortment of simple and complex organic (carbon-based) molecules out of the basic components of the atmos- phere. As these molecules slowly rained into the early oceans, a kind of primordial soup was created. Via the ultraviolet radiation, light- ning, volcanic action, and other forms of heat and energy, this soup was able to slowly combine the organic molecules into ever more com- plex forms: first simple amino acids, then organic macromolecules, then single-strand RNA molecules, and finally simple viruses. The only trouble with the soup theory is that is almost definitely wrong! The time required for it to work is statistically greater than the lifetime of the Earth.

The time is only statistically greater, however, and anything is possible.

.. Various explanations have been put forth to account for this time discrepancy. The most popular of these is the seeding of the early seas by organic molecules from space. This seeding could have been either through organic molecules present in the original formation of the Earth, or from later bombardment by meteors or more likely comets containing the organic compounds (a cosmic soup mix). None of the compensatory theories put forth are very likely, however.

This brings us to the sandwich theory. The sandwich theory states that complex organic molecules formed on the surface of undersea crystalline rocks, such as those surrounding volcanic vents.

The name “ sandwich theory” comes about because the active area is sandwiched between the sea and the rock. Besides, what scientist could resist the “ soup and sandwich” pun! Free-floating molecules in the water tend to cling to smooth surfaces. This surface effect allows various molecules to gather in one place.

Ultraviolet energy from the sun or, more likely, heat from volcanic vents, would allow this gathering of simple molecules to combine into more complex organic molecules rather easily. Some of the simplest organic molecules are scums, easily formed on flat surfaces, which themselves are sticky and gather more simple molecules. Within these scums, ever more complex molecules are easily formed. These more complex molecules tend to be three-dimensional, and bulge outward from the rock surfaces.

This allows them to be easily washed away by the sea, forming a primordial soup not of basic simple mole- cules, but of the far more complex and already evolved RNA macromole- cules and possibly even viruses. Viruses are fundamentally RNA and amino-acid conglomerates with many life-like properties.

Although it is open to debate as to whether or not they are themselves alive, viruses are definitely right on the edge: simpler things are clearly not alive, while more complex things clearly are. One aspect of the sandwich theory is that at undersea volcanic vents today life may still be evolving from basic components! This exciting possibility is being carefully investigated and holds great promise for the future. The Great Pollution After the virus, life was off and running. During the next 500 mil- lion or so years, viruses evolved into simple prokaryotes, single- celled living beings without a cellular nucleus. In this case, blue- green algae, the first plants.

This marked the beginning of the Proterozoic Era, about 2.

5 billion years ago. Blue-green algae are blue-green because they possess that truly wondrous molecule, chlorophyll. It is chlorophyll which makes possible the production of food directly from sunlight and the carbon dioxide in the atmosphere. This is the process of photosynthesis.

A side-effect of photosynthesis is the generation of free oxygen as a waste product. Free oxygen combined with itself and the methane and ammonia in the atmosphere to form ozone, water, free nitrogen, and more carbon dioxide. Over the next billion years, blue-green algae polluted the Earth with enough free oxygen to completely change the entire chemistry of the world.

Gone was the pristine methane, ammo- nia, and carbon-dioxide early atmosphere, to be replaced by a corro- sive mixture of free nitrogen and free oxygen, surrounded by a thin layer of ozone.

It is this corrosive nitrogen/oxygen atmosphere that allowed the evolution, about 1. 5 billion years ago, of chlorophyll-less creatures such as bacteria and protozoans. These creatures were active, like the oxygen they consumed. They preyed on the algae (and each other) for food, and were the first animals: very early proto-cats. The production of free oxygen also altered the structure of the very rocks themselves, causing a slow but radical geologic change. Blueprints Protozoans are eukaryotes (cells with a central nucleus).

The secret of all but the simplest lifeforms is locked in that nucleus: the chromosome.

Virtually all living things have several different chromosomes in each cell. These chromosomes comprise a set, which is itself a blueprint. In a multi-celled creature, each cell contains an identical set of chromosomes. A cat, for example, has 38 chromosomes per set, with an identical set in each and every cell, except sex cells. Each cell of a cat contains within itself the code for the complete cat.

A chromosome is itself composed primarily of a thin protein membrane enclosing a bit of water and a single molecule of DNA (deoxyribonu- cleic acid). The DNA molecule is composed of two long strands wound around each other in a double helix (like two intertwined springs), with each component of a strand connected to the opposite strand by a crossbar or rung. If the double helix were laid flat, DNA would be ladder-like in appearance. The evolution and concept of DNA is awesome in its potential, and awe- inspiring in its simplicity and beauty.

There are only six simple compounds that go together to make up DNA, phosphate and deoxyribose alternate to form the helixes while four amino acids make up the rungs. It is not the number of differing compounds that provide the secret of DNA’s success, but rather the number of rungs in the ladder (uncounted millions) and the order of the amino acids that make up the rungs. The four different amino acids are arranged in groups of three, form- ing a 64-letter alphabet. This alphabet is used to compose words of varying length, each of which is a gene (one particular letter is always used to indicate the start of a gene). Each gene controls the development of a specific characteristic of the lifeform. There is an all-but-infinite number of possible genes.

As a result, the DNA of a lifeform contains its blueprint, no two alike, and the variety and numbers of possible lifeforms has even today barely begun.

Sex There was a small problem with evolution up to this time: it was asexual. A cell multiplies by dividing! That is, once it has accumu- lated enough material to make another cell, it does–by dividing in half. This process is called mitosis. In highly simplified form, when a cell undergoes mitosis, its chromo- somes duplicate, move to opposite sides, and the cell divides in two.

Each daughter cell is an exact copy of the parent cell, barring muta- tions. Since evolution depends upon change, asexual evolution is wholly dependent upon random mutation, and thus very slow. It took almost 4 billion years, about 85% of the Earth's existence so far, to evolve up to the complexity of protozoans. What was needed was a means of speeding up the process. What was needed was sex! At first, sex had nothing to do with reproduction, not directly, anyway. The protozoans would get together, merge, swap a few genes, the separate and go their ways.

This chromosome-swapping allowed them to pass around and share an advantageous characteristic. In order for the sexual merge to occur efficiently, the concept of a double chromosome evolved. In this form, chromosomes are doubled and paired. This gives each lifeform two of each chromosome (so far), and hence two of each gene. Thus, after a sexual encounter, a protozoan had two of any given gene.

They may both be the genes it originally possessed, both be the genes the other protozoan possessed, or one of each. If, due to a mutation somewhere along the line, one of a pair of genes had a slightly different code than the other, the protozoan would assume the characteristics of the dominant gene (unless they are identical, one gene is always dominant over the other). It would, however, keep the recessive gene, and may pass it on (or not) at its next encounter.

The tendency is then for dominant genes to quickly spread through a community. This effect was clearly demonstrated in a recent experiment wherein a small group of a penicillin-resistant strain of the bacterium gonococ- cus was merged with a much larger group of normal gonococci. After a short while, all bacteria in the test were penicillin-resistant.

The bacteria had sexually interfaced and shared the genes that contributed to penicillin resistance. After the discovery of sex, the protozoans would occasionally merge and share protoplasm. They would then separate and go their individu- al ways, reproducing asexually. At some point in time, a mutation occurred in which a cell would divide not into two daughter cells, but into four half-cells, or gametes. Each of these gametes contained half of each pair of chromo- somes, comprising a half-set. The urge to merge was all powerful, and quickly carried out.

The mutation, however, was dominant. As a result, so a whole colony of protozoans was dividing into gametes, a process call meiosis, and quickly merging in a mix and match fashion. Sexes Over the next 200 million years, the protozoans evolved into cellular colonies, the porifera. Porifera, such as today’s sponges, are truly colonies, with each cell essentially the same as every other.

No cellular specialization took place. Eventually, some cells started specializing in locomotion while others specialized in food gathering, and so forth. This lead to the evolu- tion of the coelenterates, with different cells performing different tasks. Today’s jellyfish are coelenterates. With this complexity, there could no longer be a simple random merg- ing. All this specialization required that some cells spend their time reproducing not themselves, but the creature as a whole.

These cells must, then, carry the genetic code for the entire creature.

Since the new creature produced by a division and merging would start as the merger of two gametes, hence a single cell, it follows then that all cells in a creature must contain the entire genetic code for the creature. This is indeed the case. Those cells that specialized in reproduction must produce gametes that attract each other. If all were identical, there would be minimal attraction, so the concept of opposites arose.

The gametes became divided into two groups: sperm (male), and eggs (female). If there are opposite gametes, there are opposite reproductive organs to produce them. Voila, male and female creatures. This proved to be so efficient at mixing the gene pool that it became a survival characteristic. Those species had the greatest urge to merge sur- vived, and elaborate and downright peculiar means have evolved to ensure the urge to merge.

Sexual reproduction has been the norm for virtually all species more sophisticated than a bacterium ever since. In the Sea Since the great pollution, everything ate everything.

Except the algae, who were (and still are) the bottom of the food chain: every- thing ate algae, directly or indirectly. About 570 million years ago, some critters became tired of being eaten, and decided (so to speak) to do something about it. Hard parts evolved, most noticeably shells, and the Paleozoic era began. The first things to evolve shells were, not surprisingly, mollusks.

They shared the oceans of their day with a grand assortment of cepha- lopods (head-footed creatures, such as squid and octopi), arthropods (jointed-footed creatures, such as lobsters), annelids (worms), and echinoderms (spiny-skinned creatures, such as starfish). All of these forms survive today, though specific creatures don’t. The evolution of the annelids and echinoderms was soon followed by the first primitive chordates (creatures with a central nervous system). The central nervous system allowed co-ordination between the various parts of the body by channeling their neurological signals through a central organ, the brain.

By 500 million years ago, the early chordates had become vertebrates (creatures with skeletons, although of cartilage and not bone) had evolved.

Primitive jawless fish swam the seas. Current examples of jawless fish include the lamprey. Cartilage evolved into bone, and led to the evolution of osteichthyes, the first bony fish. Most of today's fish are bony, though there are still some cartilaginous fish around, such as sharks. Some 405 million years ago, two significant events occurred.

The obvious event was a sudden proliferation in the number of fish–fish became the dominant lifeform in the sea. A more significant but quieter revolution was also taking place: the plants were invading land, rapidly changing rock and sand into topsoil, and laying the paths the animals would later follow.

Ferns evolved shortly thereafter, and were present to greet the ani- mals as they left the sea. These animals were arthropods: scorpions, spiders, and bugs. Arthropods still outnumber all other species of land animal life except the microscopic. Of concern to us at this time is the evolution 370 million years ago of rhipidistan, the first lungfish, which were the direct ancestors of all higher forms of life: amphibians, reptiles, birds, and mammals.

These early lungfish lived in the coastal bogs and estuaries, occa- sionally venturing onto land for brief periods. On the Land By 345 million years ago, rhipidistan had evolved into eogyrinus, the first amphibian and a true land animal. The vertebrates had invaded the land. Amphibians were still tied to the water, however.

Their eggs had no shells, and had to be laid underwater. The young were (and still are) born with gills, which they lost as they reached adulthood.

About 290 million years ago, a creature called eosuchian learned the trick of enclosing its eggs in a calcium shell: the first reptile had evolved. Unlike amphibians, young reptiles did not have gills and did not require standing water. They soon developed scales to preserve body moisture as well.

The Paleozoic era came to an abrupt end some 230 million years ago. Most of the marine invertebrates, fish, amphibians, early reptiles, and everything else vanished. The first Great Dying had occurred. Great Dyings The history of the Earth is punctuated with many Dyings and two (maybe three) Great Dyings.

In a Dying, vast numbers of species vanish suddenly (geologically speaking) over a wide area. In a Great Dying, this area is world wide. Such an occurrence leaves uncounted ecologi- cal niches empty: those species that do survive the Dying are then presented with an opportunity to undergo rapid radial evolution, a phenomenon wherein each surviving species quickly evolves to fill as many ecological niches as possible.

The reasons behind the Dyings are not clearly understood. Possibili- ties include asteroid impact, climatological change, volcanic activi- ty, and disease. Whatever the causes, their occurrence is clearly established.

Two (three) Great Dyings occurred in Earth's history. The Permian Great Dying, 230 million years ago, terminated the Permian period and the Paleozoic era. The Cretacious Great Dying, 65 million years ago, terminated the Cretacious period and the Mesozoic era, and brought about the demise of the dinosaurs. Both these Great Dyings are gener- ally believed to be the result of asteroid impact, though other expla- nations are possible.

The argumentative Quaternary Great Dying is currently underway, and promises to destroy the greatest number of species of any Great Dying. Its cause is man. Reptiles The Mesozoic era had begun. The surviving eosucians evolved into the anapsids.

The early anapsids had an interesting problem to face: body heat. Coincident with the Permian Great Dying (possibly caused by the same event) the climate became cooler. Being cold blooded, the anapsids would assume a body temperature about the same as that of the sur- rounding air. This meant that they simply couldn't get their motors turning over on a cold morning.

They solved this problem through solar power. By evolving huge fins on their backs, they could position themselves broadside to the sun on a cold day and absorb large quantities of solar energy. Once they were warm enough, they could then face to- wards or away from the sun. One can see several drawbacks to this scheme: cloudy days, strong winds, etc. These sail-backed reptiles are often depicted in grade-B monster movies by gluing a fan to the back of an iguana.

As a dominant group, the anapsids were short-lived, surviving today only as the turtles and tortoises.

They evolved into four other reptile groups: the diapsids, which became the dinosaurs, pterosaurs, lizards, snakes, tuatara, crocodiles, /alligators, and birds; the euryapsids, which became the plesiosaurs; the parapsids, which became the ichthyosaurs; and the synapsids. The dinosaurs, pterosaurs, plesiosaurs, and ichthyosaurs are all extinct (except for Nessie, the Loch-Ness Monster, a lone surviving plesiosaur [if you are a believer, that is]). The lizards, snakes, tuatara, crocodiles, alligators, and birds are still with us.

Mammals The final group of Mesozoic reptiles, the synapsids, would not normal- ly have attracted attention. They were small inconspicuous quadrupeds with only one claim to fame: they developed mammalian characteris- tics. One group, the theriodonts, became the ancestor of all mammals.

As reptiles, the synapsids became extinct 170 million years ago. About 225 million years ago, the theriodonts evolved into the panto- theres, the first monotremes.

The first monotremes were small, insec- tivorous, shrew-like creatures about 6 inches long. Monotremes are mammals, but barely so, and survive today only as the platypus and the echidna found in Australia and New Guinea. They have very poor internal temperature control, being only somewhat warmblood- ed, are the only mammals to produce venom, are the only mammals to lay eggs, and, though milk-producing, are the only mammals without teats the milk is secreted directly though the skin and lapped by the young). About 200 million years ago, the pantotheres evolved into metatheres, the first marsupials.

Unlike a monotreme, which lays eggs, a marsupi- al gives birth to live young.

These young are very premature, and must crawl into a marsupium (pouch) where they attach themselves to teats and receive nourishment while they continue to develop towards self-sufficiency. The kangaroo and opossum, among others, are today’s surviving marsupials. The first marsupials were not much different in appearance from their monotreme forebears, being shrew-like in appear- ance and about 6-8 inches long. With marsupialism, a mother no longer had to provide all the early nourishment for her young in the yolk of an egg, but could nourish her young as she herself was nourished–sort of child-bearing on time payments. The young also had the advantage of being able to flee danger, via mom’s legs, whereas an egg is easy prey.

Good as marsupialism is, it still exposes the young to the world when they are most vulnerable: a new-born marsupial is little more than an embryo, (a newborn opossum is about the size of a bee, a kangaroo a little over an inch long). This problem was corrected by the evolu- tion of the metatheres into eutheres, the placentals, about 100-80 million years ago, in the northern hemisphere. The placenta is a complex organ allowing nutrients in the mother’s bloodstream to be passed to the fetus’ bloodstream, with waste products passed in the reverse direction, while not allowing a direct connection between the bloodstreams. The placenta of a marsupial is very primitive and inefficient, hence the premature birth, whereas that of the placentals is a truly wondrous organ.

The young could now remain within the mother’s womb, receiving nourishment directly from her, until relatively well developed and more ready to face life. The marsupials and placentals were both drastic improvements over the monotremes, and seemed to have divided the planet between them: for a while marsupials dominated the southern hemisphere while placentals dominated the northern. As the placentals grew more numerous they gradually forced out the less-efficient marsupials: Today, the only significant marsupials left worldwide are the opossums, which survive because they are so fecund. The dominance of placentals is firmly established except in Australia and a few surrounding islands, which had broken from the Asian conti- nent after the marsupials had dominated the south but before the placentals had spread down from the north.

In pre-colonial Australia marsupials were to be found in all the mammalian ecological niches (there is even a marsupial “ cat”) except for the aborigines (who arrived by boat), the dingos (wild dogs, which arrived with the abo- rigines), the bats (which flew in), and the surviving monotremes (which defy logic all around).

Modern man has introduced many other species of placental, most notably the rabbit and the mongoose, and the long-delayed marsupial/placental struggle is now taking place in Australia, with the marsupials losing. Near

Cats The Cretaceous Period and the Mesozoic era came to an abrupt halt with the Cretaceous Great Dying, 65 million years ago. Suddenly, the Earth finds itself with virtually all of its dominant species wiped out: no more dinosaurs, pterosaurs, or plesiosaurs [Nessie?], and very little of anything else.

The Cenozoic era had arrived. Of those few creatures which survived the Cretaceous Great Dying, one was a small, active, adaptable, shrew-like euthere, about 7-8 inches long, who then experienced rapid radial evolution. By 60 million years ago one of its many newly-evolved descendants was miacis, who ate flesh and was among the first truly carnivorous mammals.

Miacis was somewhat martin-like in appearance. His distinguishing characteristic was his teeth, which set the basis for all modern carnivores. He had a dental plan with incisors, canines, premolars, carnassials, and molars in each jaw. The carnassials were a new invention, being designed specifically for the cutting of flesh in a scissor-like action. Modern cats and dogs have carnassials, humans do not.

These advanced teeth were fundamental in the demise of other predators, allowing him to make more kills and to better digest his prey, both of which meant more and larger miacids and fewer others. Miacis was a short-term creature, quickly evolving under the pressure of competition into several different miacids, each of which went on to become a differing type of carnivore. By 45 million years ago, one of these differing creatures was profelis, the forerunner of all cats. By 40 million years ago profelis had evolved into hoplophoneus and dinictis. The primary differences between hoplophoneus and dinictis were in jaw structure. In hoplophoneus the upper canines increased drastically in length to become stabbing weapons, with corresponding changes in the jaw hinge to allow the mouth to open extra widely.

In dinictis the upper and lower canines became more balanced and the jaw hinge developed more muscle.

Both were halfway between a cat and a civit in appearance, long in the body and tail, short in the legs; both had definitely cat-like heads; and both were plantigrade: modern cats are digitigrade and walk on their toes, good for running, while people are plantigrade and walk upon their whole foot, good for stand- ing. About 25 million years ago, hoplophoneus had evolved into smilodon, the famous saber-toothed tiger. Smilodon was definitely a cat in appearance, walking upon his toes and all, but had a somewhat flat- tened head with a small brain pan (he wasn’t very bright). Smilodon was the end of his line, and vanished some 12, 000 years ago.

The exaggerated tooth structure of the hoplophoneans and especially smilodon was a response to the evolution of the titanotheres, the giant mammals of the early Cenozoic.

These animals were huge, with correspondingly thick and/or shaggy coats, which the dagger-like canines of the saber-toothed tiger could pierce to deliver a killing blow. The largest of the titanotheres, and the largest land mammal ever, was the ground sloth baluchitherium, which stood 18 feet at the shoulder (the height of a tall giraffe), and whose head reached 26 feet off the ground. Real Cats While hoplophoneus was evolving into smilodon, dinictis was also evolving. Dinictis itself had one seemingly trivial, but really very fundamental characteristic: it had three eyelids. Modern cats, and many related species, have three eyelids, the third being the haw, or nictitating membrane.

Dinictis evolved into pseudailurus, which was definitely a cat in appearance, not too different from some of the more extreme species of modern cats. Its teeth were identical in structure to those of the modern cat and it was digitigrade, walking on its toes (though not quite as well as the modern cat), but it still had a small brain pan. Some 18 million years ago, the oldest of the modern genera of cats evolved from pseudailurus: acinonyx. The modern cheetah is the only species of acinonyx surviving today and is actually little changed from its early ancestors. Some 12 million years ago, pseudailurus had evolved into felis, the modern lesser cats.

Two of the first modern cats to appear were felis lunensis, Martelli's cat, and felis manul, Pallas' cat. These cats had larger brains, surprisingly human- like in structure, and were in all ways true modern cats. Martelli's Cat has become extinct, but Pallas' Cat is still very much with us, the oldest living species of genus felis.

By 3 million years ago, the last of the modern genera of cats evolved, panthera, the greater or roaring cats, to which the tigers, lions, leopards and their kin belong.

Somewhere between the First and Second Ice Ages, 900, 000 to 600, 000 years ago, a very special cat, felis sylvestris, made its appearance, and is still with us as the European Wildcat. During the Second Ice Age, the glaciers moved down from the north, driving him southward. At the same time, the Mediterranean and Black Seas were greatly re- duced in size, providing many land bridges to the south into Africa and to the east around the foot of the Urals into Asia, allowing him to extend his domain into those regions.

As the ice receded the seas rose and the climates changed, the immi- grant species became isolated from each other by water, deserts, and mountains.

Over time, those species of wildcat isolated in Africa became the Sand Cat, the African Wildcat, the Forest Cat, and the Black-Footed Cat, while the Asian version became the Chinese Desert Cat. There were, of course, several other subspecies that, for one reason or another, didn’t survive the changing landscape and climate. One of felis sylvestris’ many offshoots was felis lybica, the African Wildcat. He is still with us, but, more importantly, he is the imme- diate and primary ancestor of all domestic cats.