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Time and Memory

Evolution and Chronology

Have you ever noticed how,
The time is always now,
Whether you're a brown-eyed cow,
Or a Mau-Mau,
Or an owl?
— Michael Bridge

"*Where did we all come from*?" "*What is it all about*?" "*Where are we all going*?" If our living brain can fashion masterpieces like sunsets in total darkness with voltage potentials, why can't it come up with those answers? If we must solve this puzzle ourselves, a good place to start would be noting any possible similarities in the questions. From a neurological perspective there is a characteristic common to all three questions. It stands out immediately if we think about it. They can be asked only by a creature with a consciousness based on chronological, past-present-future sequential time. This sort of thinking doesn't include humans until well after the age of two and would eliminate the rest of the world as well. The concept of anything going anywhere in time didn't figure into our own life for a couple of years at least. For everything else on this planet, things just are or they aren't.

We tend to think all conscious creatures think in roughly the same manner we do but conscious chronology is something modern humans learned recently late and share with no other species on the planet. The final step in human mental evolution was learning to structure time, and only recently have we learned how we do this amazing feat, the final gift that made us mindful. In learning the mechanism of conscious sequential memory, we also establish its evolutionary history. Evidence is gathering which indicates that our sense of chronological time originates with specific brain structures located in the prefrontal cortex. This area of the brain is very recently evolved in humans and matures well after birth. Jean Piaget, a pioneer in child psychology, was one of the earliest to observe and describe the stage in brain development when a child, watching a toy train enter a tunnel, instinctively glances forward to await its exit from the other end. Before that point as soon as the train is out of sight, it's out of mind. Here and gone. The child immediately loses interest. The toy train's re-appearance seconds later is unexpected and surprising. Another train? The child's train of thought derailed when the actual train disappeared from view. The mature ability to imagine without seeing, in this case tracking an imaginary train traveling out of sight in the tunnel, was called "conservation" by Piaget and it appears by degrees.

The prefrontal cortex is the last brain structure to mature so we must slide into conscious timekeeping past the age of speech. If we can't chronologically sequence our memory,. the typically childlike perspective of constant novelty is simply unavoidable. By the age of four, however, we are clearly experiencing time in a sequential, three-dimensional framework. Gradually we learn to take such a world for granted, sequencing perception into memory and perceiving time as moving forward. This may be how we humans perceive time but it doesn't mean time actually moves in any direction. The brilliant mathematician Norbert Wiener, whose concepts made the modern computer possible, made this point in his seminal work *Cybernetics*. He reasoned if time were to suddenly shift into reverse, causing the planets to circle backwards in their orbits, a space traveler arriving on the scene could detect no difference at a planetary level. Time might well run in both directions. However, it would be impossible for forward-time people to perceive a backward-time universe. For one thing, any stars going backwards in time would be pulling in light, not pouring it out. Wiener pointed out that it is impossible to see such stars, given the way human eyes work. Any communication is likewise be impossible, since conclusions would appear first, disassembling into meaningless parts as time receded. He concluded the only sure thing we can say about any universe we observe is that it obeys the same laws of thermodynamics we do. If we can't detect it, how can we really know? Perhaps "black holes" are receding suns of other times illuminating planets traveling backwards towards the past. With us, however, time seems to move forward even though we're always in the present.

Classical Greeks had two words for time, *chairos* and *chronos*. *Chairos* is "just in time" or "at the right time" or "the time of your life". It is personified by a little god in a moving chariot or even, sometimes, a god on wheels. *Chronos* is sequential time, time we perceive as passing, the chronology we use whenever we remember or predict. Once we sense *chronos*, we know it's all going to be over some day. Little wonder the Greek titan Chronos is depicted as a fearsome ancient Father Time, a huge, bearded giant who consumed his own children. In India, the Sanskrit *kala*, time, is reborn in the fearsome Kali. The fearsome black (*kalo*) goddess is garlanded with skulls, drinks blood, conquers all and, just like time, gets everyone in the end. Indian parents name their little girls Durga, Lakshmi, Tara, all the great goddesses but never Kali, most powerful of all. Only Shiva, timeless Shiva, could ever love Kali.

With the rest of the world remaining entirely in *chairos*, the last evolution of the human brain placed us as a species on a chronological escalator traveling from the past to the future. When we began to transform images from past presents into future predictions we found ourselves confronted with multiple mental problems arising from this new form of conscious time keeping. If our perception of chronology turns out to be a specific evolutionary step, it could expand our understanding of the mechanisms of human perception. At some point we obviously acquired what may be a unique talent and with it the host of time-related mental problems which plague us all. The moment we are able to sense the passage of time, we never seem to have enough of it. Where did time appear? Where was the branching off that set us on the road to the mind of mankind?

Clear Memories from Chaotic Patterns

It's not easy to cook up chronological time with a human brain. Norman Ramsey, Nobel Prize winner in physics for his development of the atomic clock, points out time is measured by periodicity. From sunrise and seasons to the picosecond vibrations of cesium atoms in Ramsey's timekeepers, it is regular repetition that sets the foundation for the measurement of time. Unfortunately, measurement and perception of time stay linked only if the observer has no periodicity, or at least one that remains constant. For example, the brain normally runs data-gathering at the same speed as interpretation. Still, a major problem with using a biological basis for time perception is that neurons simply aren't as tough as silicon. Things happen. The body's response to a very stressful event is always an immediate release of powerful hormones. One effect is to speed up neural activity dramatically in certain higher brain areas. It makes excellent sense to increase the intake speed of perception when something exciting or dangerous may be happening. We need all the information we can get and we need it fast. Neural firing can increase by three hundred percent.

This creates problems for consciousness. By gulping down information faster we make the world seem to slow down. This effect, described in greater detail in Chapter Nine, is analogous to speeding up a movie camera to create the illusion of slow motion. When parts of the brain get out of synchrony, all sorts of weird things start happening. Since this indicates the perception of time must vary according to the situation, it could give Einstein a headache. Is the speed of light really an invariable if an observer's perception of time itself speeds up and slows down from time to time? If time and space are interdependent, but time is variable relative to the observer, is space also then a variable? Could we experience infinite space during a moment of timelessness?

Putting aside such speculation for the moment, it appears there are two fundamental processes basic to our perception of time. The first has to do with serial storage of neural based patterns. The second has to do with the level of detail we can recall. Once again, we can draw useful images from the field of information sciences. The ways and means of memory are absolutely essential to the science of data processing. In fact, the definition of the computer itself was originally a device able to instruct itself from an internally stored memory. The better the memory, the more complex the instructions and the functions of the computer can be. As to how patterns are created in the brain, we simply cannot do anything in a physical environment without leaving some sort of physical trace. Total and complete disappearing acts happen only in imaginary places. Every time any neuron sums and fires, something complex happens in a physical environment. There must be traces left behind, both in physical molecular changes and in the electrical conductivity at each of the connections. This is covered in greater detail in Chapter 8.

Remember, the average brain has at least several hundred billion neurons. Using less than one percent of its capacity for anything from soup to nuts means at least a hundred million neurons in action. If an average neuron has about 200 dendrites, 200 outputs, a pulse down just one aborated axon tree would leave traces in 200 other neurons connected to that one cell. Adding the other 99,999,999 neurons gives us numbers like "the number of stars in a galaxy". This is what happens the moment we wake up and smell the coffee. Smelling a cup of coffee, in fact, calls into action a full chorus of cellular choreographies, all interpreted through our personal past experience. Neurobiologist Walter J. Freeman of the University of California at Berkeley describes the process: “When an animal or a person sniffs an odorant, molecules of the scent are captured by a few of the immense number of receptor neurons in the nasal passages. Cells that become excited fire pulses through their axons to the olfactory bulb.”

“The bulb analyzes each input pattern and then synthesizes its own messages, which it transmits via axons to the olfactory cortex. From there, new signals are sent to many parts of the brain, including the entorhinal cortex where the signals are combined with those from the other senses. The result is a meaning-laden perception, a gestalt, that is unique to each individual. For a dog, the scent of a fox may carry the memory of food and the expectation of a meal. For a rabbit, the same scent may arouse memories of a chase, and fear of attack.”

An original perception creates an instant temporary network of electrochemical trails as the pulses proliferate outward through millions of interconnected neurons. Like an after-image of a brilliant fireworks display, the remnants of the event remain in innumerable synaptic and intercellular changes created when the energy came coursing through. If we could recreate that electrochemical tapestry perfectly we would not just remember experiences. We would relive them completely. It would be a perfect replay of the entire virtual moment we once experienced. Normal recall, in comparison, recreates the image or thought with a very incomplete pattern..

If simple microscopic dots on a plastic laser disc provide CD quality music, we might wonder why we can’t simply play back our past. The reason is the neurological “afterimage” is not only imprecise, it serves only as a physical foundation for even more subtle patterns in a moving electrochemical presence weaving and pulsing throughout the brain, invisible except as a mathematical event. The brain is alive and thoroughly interconnected. The ongoing process of consciousness must be chaotic to the extreme. Still, as a pole hammered into a stream will have an effect on the entire flow of water passing around it, any physical change, no matter how small, will affect neural flow patterns in definable ways. This is why every thought must change the flow of consciousness a tiny amount. Nothing remains unaffected. The only thing that remains constant is the flow itself, which may be comforting to Taoists and Buddhists who regard the pure undefined mind as the only thing that doesn't change.

It is this chaotic activity which makes it so difficult to compare the brain and a computer. Not only is everything alive, the working activity of the brain is simply too complex, on the grandest of scales, to be comprehensible to us. Playing back a specific picture would as hard as extracting the 9th Symphony from Niagara Falls. With the right microphones and filters one might pull a little Beethoven from the totally random "white noise", but how can we get patterns good enough to use in any sort of comparative chronology out of such confusion? The closest we can come to pattern recognition in a chaotic environment unfortunately requires capabilities that we ourselves cannot mentally image any more than we can see "red receding". Although chaos may blur signal and noise to otherwise indefinable levels of confusion, patterns as pretty and defined as snowflakes can be located within these environments. The problem is that these patterns can be detected only through a sophisticated mathematical structure called "quantum time". Since there is no way in the world a human brain can think in quantum time, there may be no final Rosetta stone of consciousness We may never witness the subtle electrochemical patterns rippling and shifting through neural channels and biochemical bridges. The final language of the mind may be indefinable because it may be undetectable. We may indeed create time with huge holographic chaotic memory patterns, but we may never locate them regardless of how hard we try.

Nobel Laureate Sir Francis Crick, discoverer of the structure of DNA, turned his genius to the mind recently. Among his conclusions was one that consciousness is timed, put into discrete frames, in regular neural pulses. Still, neither he nor his colleagues at the Salk Institute has suggested any way we could comprehend human consciousness or discuss it from a critical perspective. To be conscious of consciousness and still discuss it at the same time would require a mind one step more complex than our own. We can imagine only what the mental lens of our mind can resolve and this is may be beyond mental resolution. Anyone who could know it or explain it completely would be operating with the equivalent of a neural upgrade and probably wouldn't be normal enough to make sense to us. But just because we cannot look at consciousness with science does not mean that it does not exist. The Indian philosopher Chandrakirti insisted on the distinction between "that which cannot be found" and "that which does not exist." Consciousness certainly exists but we have to be flexible about locating it. Take angels for instance. Perhaps angels learned to avoid telescopes or maybe they just left town when Copernicus closed Ptolemy's crystal condos. Who knows? It doesn't mean they absolutely don't exist, just no place where we can find them. Likewise consciousness is there but we may never be able to understand it in our own terms.

Excepting in rare neurological or dream events, then, memory is rarely replayed. Furthermore, those neural patterns not reinforced by repetition or remembrance lose their linkages eventually and dissolve into the unconscious. Each moment was in sharp focus when it happened. It was all there once, senses on-line, but unless we replay sequences over and over again in our memory the patterns fade and are soon lost to conscious recall. Studies by James Kreuger of the University of Tennessee demonstrated the brain releases special substances, *cytokines,* during sleep. These induce special firing patterns among various neuron groups. Kreuger suspects since even major connections are not used every day, this may exercise them during sleep to help preserve important associations and connections for future use. Still, all but the most extended and repeated networks lose definition over time, and fade from conscious memory. Every instant left a true record once but depending on the intensity of the event, the attention we gave it, and the number of times we recall it, stray currents soon wash the labels off most of our files. They fragment, and become lost in our warehouse of forgetfulness where they fall apart and compost into the general unconscious image archive we use for imagination and dreams. Hindus say that over endless lifetimes, the effects of *karma*, intentional activity, eventually vanish. In the endless unconscious of forgetfulness we forgive all our debts, and there all our trespasses will likewise be forgiven and forgotten.

This is actually a blessing. If our memory remained conscious, we'd be constantly distracted. We are actually living in the present so it is better not to be dealing with too many after-images on the screen of our conscious perception. Asked about his reputed power to recall his previous lives, the Dalai Lama answered it was more important to be attentive to the present. His difficulty remembering previous lives didn't bother him. "I know people who cannot remember what they did last year," he added with a chuckle, "So not remembering an entire lifetime ago is not such a concern to me." In the United States there was a flurry of court cases involving "recovered memories" as the basis for the prosecution of accused sex abusers. Without a doubt such tragedies occur, but as there is no way that a child before the age of three can recall anything in sequence it is equally impossible that any memory that old could survive the normal distortions of organic degradation. We don't have hard drives in our head and there's no "hard memory" either. If we forget it, it's never coming back clean. If it happened before we were three, we can't possibly remember it in any reflective context.

It might seem memory networks should affect our brain cells but it's unlikely. The physical complexity of such neural impressions could easily encode vast amounts of specific data without altering the ongoing functioning of any neuron. Like decals on a racing car, tiny molecular changes won't affect speed or performance. Each neuron, depending on its past, carries modifications enabling it to function as part of numerous interlinked patterns, each appropriate to the moment. No single cell has to do very much or know anything at all. In a sports stadium display of rippling squares, each participant has only a few pieces of colored cardboard, a tiny part of the whole design. The images are never visible to the people actually creating them, just like neurons, each a little living voice helping sustain and modify the immense energetic chorus of patterns flowing around them and through them and beyond them. Day and night, each neuron does its digital duties. At the same time the remnants of experience, molecular reminders of our past, are modifying complex and interconnected patterns throughout the brain. Some networks fade. Others are reinforced and extended by repetition. Some interconnect to long-lost pattern trails, merging and creating new combinations energetic enough to surface as sudden thoughts, ideas, insights and intuition. There are unconscious and intricate muscle routines circulating in the cerebellum. Visual patterns lie dormant in the visual cortex, emotional patterns in the limbic system and verbal patterns in our speech centers. Once we wake to the awareness of our own memories, we take it for granted. But clear chronological memory itself was a hard blessing, and it came together over a very long time. For that, we needed the largest brain on earth, and we needed one final tune up.

Banking on Brain Mass

There is no specific location for a complete memory in the brain. Conscious recall is as dynamic as the brain that is making it. Although the ancient hippocampus seems to have a central organizing role and the prefrontal areas store, scan and serialize, memory still remains predominantly a function of amount, complexity and organization of available brain mass. Regard the caterpillar, for instance. It hatches, eats leaves, spins a cocoon and turns into a moth if it’s lucky. Its nerve cells are much less complex than a human’s, and it may have only a few dozen interconnections for each. But still, it has over 350,000 of them. It needs every last one to operate the 200 muscles it uses to chew leaves, and that’s just for starters.

The computational power of a caterpillar “brain” soars above any supercomputers we have devised. Computer-controlled assembly lines fabricate and weld automobiles with a dozen or so process computers. The very idea of 350,000 little living processors packed into one part of an insect is awesome. If computers reach such complexity they’ll probably be able to crawl about and turn into tiny helicopters. Maybe they’ll lay eggs too. At this basic level of neural mass and complexity there is enough internal memory to run the caterpillar, but it's all used up operating the insect. The surest test we have for conscious memory is learned alternatives and insects learn practically nothing. The longest memory observed for an insect so far is about fifteen minutes for the scarab, or dung beetle. It actually remembers to feed its young. We can employ operant conditioning using basic stimuli like electric shocks or chemicals and get responses from flatworms, but reacting to pheromones is not learning. If only they had the minds to appreciate it insects could be ideal Zen monks. Always in the now, and always in the flow, they expect nothing because nothing happens more than once. A brain that can't recall can't predict. No crises, no surprises. Just processes. So it goes, forever.

As life forms evolved into greater complexity their brains grew to handle additional tasks of monitoring and control. As the brain grew, memory grew until it could store enough acquired information to help guide an animal's activity from one moment to the next. Fish and lizards are difficult to train but by the time a brain reaches 20 cubic centimeters there is real learning ability. This is sufficient brain mass to retain experience and initiate vague forms of purposeful repetition to improve interaction with the environment. Complex learning appears after the reptiles. By the time the brain has grown to 150 cc's, an average dog, there is excellent perception and memory enough to learn, recall, anticipate, and dream. There isn't enough capacity in 150 cc's, however, for intellectual discrimination, philosophical meaning, specific self-consciousness, or even three-dimensional color vision. Memory must be reconstructed from complex stored patterns. Most creatures simply have neither the capacity to store much peripheral detail nor our ability to sequence images into a chronology. Without a chronological consciousness, animals cannot make any conscious plans. Even chimpanzees, at 300 cc's the smartest of the smart, never planted a garden. The immediate future is all they have in focus. If they could recall even a few seasons in sequence they could remember the progression of seed to fruit and grow their own. They never have.

Self-consciousness is also limited by memory. We must be aware of the differences which help us distinguish ourselves from each other. We know ourselves clearly only to the extent that we remember and understand past experiences that affected us and formed our personality. Conscious and unconscious memories underlie all our likes, dislikes, hopes and fears. As our sense of self is dependent on the detail and subtlety of our recall, the better memory we have, the more self-conscious we can be. Animals, for all their variegated plumage and behavior, are remarkably similar to each other. If dogs had personality traits as complex as humans they wouldn't need their noses to greet each other. Reptiles are so lacking in observable personality their manners are truly reptilian. They never say they're sorry. They can't. Remorse takes a lot of RAM and snake brains simply can't run complex routines.

It is possible, however, to shame a spaniel and one can actually embarrass gorillas and other great apes. Bigger brains do more than swell heads. They allow development of complex personal and social structures. In comparison an insect has no hopes, biases, or conscious predispositions at all. It never blames, never criticizes and it never complains. There is no self, no self-consciousness, no memory and no meaning. It means more to nearly any observer than it can to itself. Its parts are busy operating at full capacity getting the job done with a mere cubic centimeter of brain matter. There is no recall. There is no time for recall. Without recall there is no time, no beginnings and no endings. The silkworm mechanically pulps some mulberry leaf. A bird overhead sees the silkworm and recalls a meal. A human notices the bird, and predicting what birds will do to silk worms, shoos the bird away. The silkworm mechanically pulps some more of the mulberry leaf, a living fiber manufacturing plant. No time for silly things. No time at all. It pulps some more mulberry leaf. No time like the present; no memory of the past, no hope for a future. Without a thought, the silkworm munches on.

Overall increase in brain mass provides room for better memory and a more refined consciousness. However, it should be stressed evolution never equates sheer bulk with intrinsic value. If this were the case, we would all be under the rule of blue whales. Elephants have much larger brains than humans but they're still using their noses for hoses and working for peanuts. In terms of species, from an evolutionary standpoint, whales are closely related to seals. A very big seal isn't more complex than a small one. It's just more seal. There is a lot of whale to operate, which increases the mass of the brain since more body cells need management. Whale learning has been observed and shown to be at "seal level", the aquatic equal of a smart dog.

This is enough memory for a sperm whale to dive down to where it expects to meet a giant squid for takeout. The giant squid, with less memory than a paper clip, never expected anything in its life, far less a large whale in the way. No matter how many pounds of neurons a giant squid was born with, if they're squid neurons it's going to be squid smart and no more. Squid nerves are like cables, so big they're visible. Compared to that level of simple consciousness even fish are savants. In this world, it seems, any species that can't remember will sooner or later serve as dinner for the rest.

Upgrading to Primate

It's been accepted since Darwin that survival often requires novel adaptation to a new environment. The last great evolutionary surge in brain development began taking place about sixty million years ago when some daredevil mammals got tired of being chased up trees and decided to stay there. If we are going to spend a lot of time jumping from limb to limb with a small bobcat after our tail, things will definitely need improvement to avoid becoming cat dinners. First, it's important to shift the eyes to the front, like a cat, for the three-dimensional depth perception necessary for judging where that limb really is. Second, good color vision is also at a premium. It helps to get the live branch rather than the dead one. It's a long drop if we can't tell murky brown from murky green. Both aid in finding fruit and catching insects, increasing food supply as well as safety.

The brain's visual area was pressured to expand as so much visual data had to be analyzed for trajectories. Most animals rely on their noses, but we can't smell our way across thin air. A little off the jump, a little off on the grab, and it's one more pre-tenderized tiger lunch on the jungle floor. Dealing with gravity in high places is high risk for anything weighing more than a bug that doesn't have wings to flap. It must have rained animals until the forebrain evolved enough mass and complexity to transform kamikaze marmosets into decent monkeys. In the process, the cerebellum doubled in size as well, accepting new specific and more discriminating control from the higher forebrain areas and creating a much finer tuned muscle response.

Luckily for lemurs and eventually for us, adding brain tissue is a simple genetic adjustment. At the fetal stage human brain tissue is so undifferentiated it can been clipped and transferred to other patients like living tofu. It grows right in. "More brain tissue" is easy evolution. It's much simpler than adding wings or claws. It can also happen much faster than we once thought. Anthropologist Karen Milton, of the University of California at Berkeley, studied two kinds of ape and made a surprising observation.

Apes have a basic diet of fruit and leaves. Fruits provide high energy but are low in vitamins. Leaves are high in vitamins but require long digestive tracts to process them. As a result, an ape with a shorter digestive tract must eat more fruit to make up for its inability to extract nutrients from leaves. Since most trees bear fruit for only a part of the year, even in equatorial climates, a fruit-eating monkey needs a complex feeding strategy full of searching and returning. On the other hand it doesn't take any recollection at all to locate leaves in a jungle. Spider and howler monkeys are about the same size but spider monkeys are fruit hunters while howlers are leaf munchers. Although the apes weigh about the same, spider monkeys are carrying around brains nearly twice as large as the howlers. Not being food may have driven us into the trees, but once we went arboreal, locating food was the next environmental pressure for a larger brain. The extreme difference in brain size between two species of modern monkey shows how quickly the brain can grow if certain conditions and diet are present.

One of our most distinctive evolutionary steps was the rapid development of the forebrain's specialized ability to recall and redirect complex muscle sequences. Although this originally evolved to allow us to perform repetitive tasks without having to re-learn them each time, our enlarged visual memories became adept at storing visual cues occurring during the learning experiences. If we find a good fruit tree, we don't want to forget the way back. A simple mindless playback may be easy for bees, but their memory chip is so tiny it only holds the most recent trip and it's forgotten a few minutes later. All primates, once mature, have much longer memories and they all seem to focus it the same way we do, with the prefrontal cortex.

When a monkey starts to learn a task, the greater amount of brain activity takes place in structures linked directly to the event, the visual and motor control areas. When the activity is repeated, however, the forebrain becomes the more active area. Once a task is learned the primate forebrain seems to sequence and trigger behavioral routines far more complex than in other species. Just like human subjects who activate word searches from the forebrain when retrieving verbal information, this sequential searching ability may be related to the necessity to recall, replay, and modify a repeated sequence of muscle patterns. This is exactly what comes into play when we learn how to play a piano, dance a tango, or take a flying leap to a swaying branch in the treetops. It was essential for grabbing swinging vines. If we jump to where it is right now, we die. If we jump to where it will be, we live. The brain must unconsciously calculate a future event and sequentially fire off millions of muscle movements in order to get us there. From a computational viewpoint, it's calculating: "Vine there now, vine moving this fast, will be about there if I jump *NOW!..Got it!*." Prediction can be a life saver even at the unconscious level.

By the time apes had their aerial acts perfected they were using the most complex muscle sequences on earth. Since they hadn't grown any new organs there were few changes in the operational parts of the brain that manage body functions. It was the finely tuned higher brain areas which evolved. Sequential pattern comparison in color and three dimensions requires giga-giga-terabytes of operational memory. In response, our visual and discriminatory areas added large amounts of new mass and specialization. The brain of the porpoise may be as complex as man's, but its complexities are more associated with hearing than sight. Primate brains are primarily visual: monkey see, monkey do. And we are so smooth at it. No other creatures are better at strong, controlled, and yet delicate movement. Cats couldn't dance if they tried.

It took all of evolutionary history to reach the mass and complexity of the original primate brain forty million years ago. Since then there have been dozens of diversions from the original line. Some adapted into gorillas, chimpanzees, orangutans, monkeys and baboons; from ground dwellers to neo-arboreal apes. Most of them get through life with a combination of wits, claws, fangs and muscle. Some lines opted for miniaturization and speed, becoming old-world monkeys and remaining in the trees. Our branch of the family, *homo*, out on the African grasslands, bet on brains. To make it possible, they started to eat better. To be precise, they began to eat more meat. It's now well known chimpanzees, given the opportunity, will readily kill and eat small animals. It is more likely our earliest ancestors were not strategic hunters but scavengers, grabbing the remains of kills brought down by the larger predators and pounding the bones with stones to extract anything edible.

"It was not just meat, but fat and bone marrow," explains Leslie Aiello of University College in London. "Such easy to digest food requires smaller stomachs and intestines, which use up less energy. That surplus began to feed our brains, which began to grow significantly." Natural law suggests enough is enough. Still, nobody has suggested recalling elephants or giraffes for big noses or long necks. The extremes are there to define the norm and there was nothing normal about our unusual brain. It just kept growing. The mass of the brain began to spiral upwards, doubling its size with billions and billions of new cells. By two million years ago, it passed 450 cc's, and it was still growing. By a million years ago, it had doubled again to 900 cc's, and still kept on growing. By 150,000 years ago, it had nearly reached its current size, a staggering 1,400 cubic centimeters of mass and complexity well beyond human understanding, capable now of the conscious perception of time as well as space.

The brains in our skulls weigh more than entire monkeys. Each made up of hundreds of billions of the most exquisitely formed neural cells on the face of the earth. If it took only 150 more cc's of these hyperconnected neurons to give apes short term prediction, recall and correction, what must have happened to human consciousness as mankind is trapped on a full ten times more? We cannot imagine. We've been thinking with 1,400 cc brains since we started to imagine and we won't have appreciably less until we die. What finally made us fully conscious humans, much less than 100,000 years ago, was when the human prefrontal cortex, already directing the smooth orchestration of muscle movement, perfected an ability to store, sequence, and monitor huge patterns into conscious recall, imagination, and prediction. At a certain point in time, our growing brain mass reached the point where the detail and energy of the patterns made them perceptible, and finally even directable. We know it happened, and we are finally beginning to understand just how it happened.