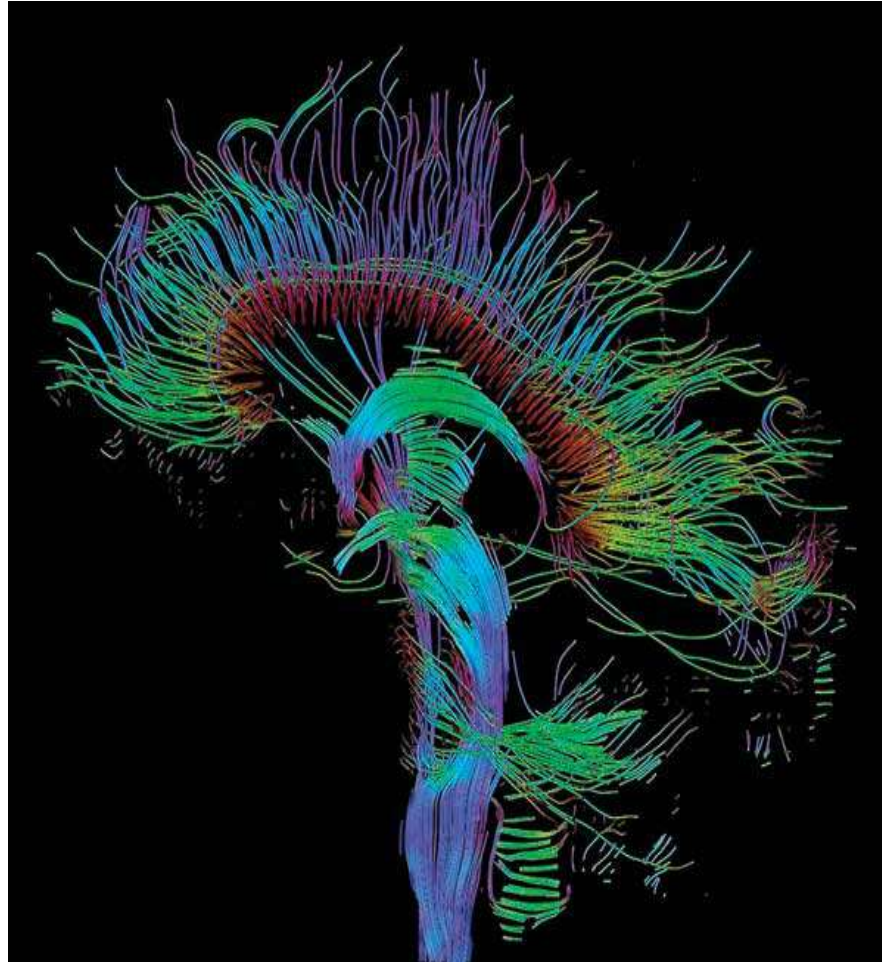


# *How Our Brain Evolved*

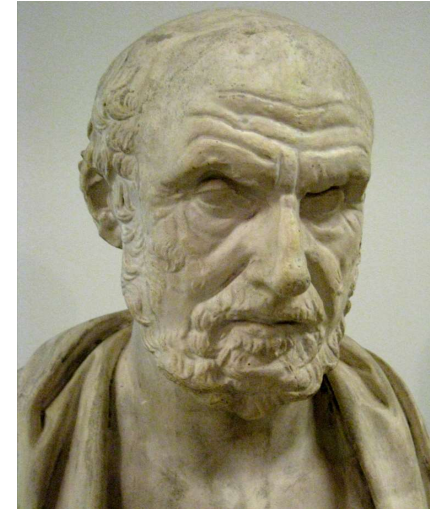


# Introduction to the Nervous System

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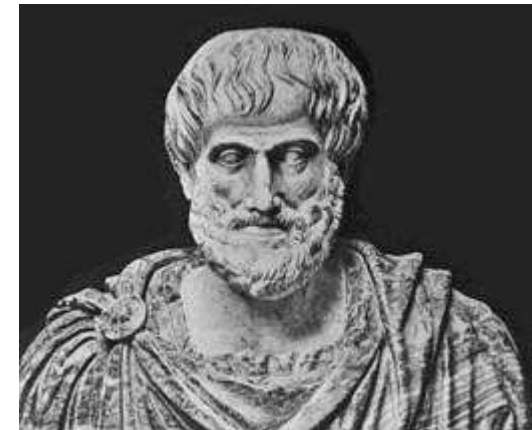
- Hippocrates (460 BCE) - Kos, Greece – Philosopher and scientist /// about physiology - “from the brain only, arises our pleasures, joys, laughter, and jests, as well as our sorrows, pains, griefs, and tears”

- *Famous Quotes: Let food be thy medicine and medicine be thy food. // Wherever the art of medicine is loved, there is also a love of humanity. // Life is short, the art long.*



- Aristotle (384 BCE) - Stagira, Greece – Philosopher and scientist /// about physiology - thought brain was a ‘radiator’ to cool blood

- *Famous Quotes: We are what we repeatedly do. Excellence, then, is not an act, but a habit. // The whole is more than the sum of its parts.*



- Today the cessation of brain activity = clinical criterion of death

# The Evolution of the CNS

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- First vertebrae (fish) occurred about 550 million yrs ago // **Spinal cord** changed very little throughout vertebrate evolution
- But the **brain** has changed a great deal over the last 20 million years.
  - greatest growth in brain occurred in areas controlling vision, memory, and motor control of the prehensile (able to grasp) hand.
  - *our hands allow us to build what our brain can imagine!*
  - Human brain structure/function developed as distinct “layers” (Called the **Triune Brain Theory**)
    - “primitive functions” placed lower in the brain (e.g. medulla oblongata)
    - most “advanced functions” placed higher in the brain architecture (e.g. cerebrum)

# Triune Brain Theory

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- The modern brain evolved in three evolutionary stages also referred to as **brain formations**.
- Each formation existed for relatively long stable periods (over 100's of millions of years) followed by the development of another formation.
- This pattern existed throughout the evolution of the vertebrate brain.
- These are the “Three Brain Formations”
  - Protoreptilian Brain Formation
  - Paleomammalian Brain Formation (Limbic System)
  - Neomammalian Brain Formation (Neocortex)

# Summary of Brain Formations



**Protoreptilian  
Formation**



**Paleomammalian  
Formation**



**Neocortex  
Formation**



The most efficient way to understand how our brain works today is to understand how the brain evolved as summarized by the **Triune Brain Theory** developed by Paul MacLean in the 1970s.

According to his theory, the following three distinct formations emerged successively in the course of evolution. **These functions associated with these three distinct brain formations now co-exist in our modern human brain.**



**Protoreptilian  
Formation**



**Paleomammalian  
Formation**



**Neocortex  
Formation**

The **reptilian brain (or Protoreptilian)** is the oldest of the three brain formations. It controls the body's vital functions such as heart rate, breathing, body temperature and balance.

Our reptilian brain includes the main structures found in a reptile's brain: the brainstem and the cerebellum (and much later in the evolutionary development - the reptilian brain included the basal nuclei and mid-brain).

How do we characterize the reptilian brain? It is extremely dependable, predictable, and reliable. It responds to stimuli with genetically encoded instinctual action plans required for primitive survival behaviors -- like exploration, feeding, aggression, dominance, and sexuality. The RB tends to be somewhat rigid and compulsive.



You can't train these animals to fetch your slippers! They are not like a dog! No emotions!

The **Paleomammalian formation** (also called the **limbic brain**) emerged with the first “stem mammals” (over 200 mya). For the first time, **emotional instincts where encoded as innate structural entities** (i.e. as nuclei). Of equal importance, for the first time stem mammals **developed the ability to remember these innate emotional experiences subconsciously as either being agreeable or unagreeable (pleasant or unpleasant).**



These memory experiences could now help **shape the behavior of mammals in terms of their experience.** Today, it is responsible for what we now call **emotions** in human beings. But these nuclei also plays a part in how we make decisions based on our “values”.

The main structures of the limbic brain are the hippocampus, the amygdala, and the hypothalamus (includes other interconnected structures – parts of the thalamus, nucleus accubens, septal nuclei, mammillary bodies, and other structures which are called the limbic lobe or simply the limbic system).

The limbic brain is the location of our **value judgments**. These are decisions that are made as **part of our subconscious brain activity**. The limbic system exert a **strong influence on our conscious behavior** because nerve tracts connect the limbic system to the neocortex with bidirectional signaling.

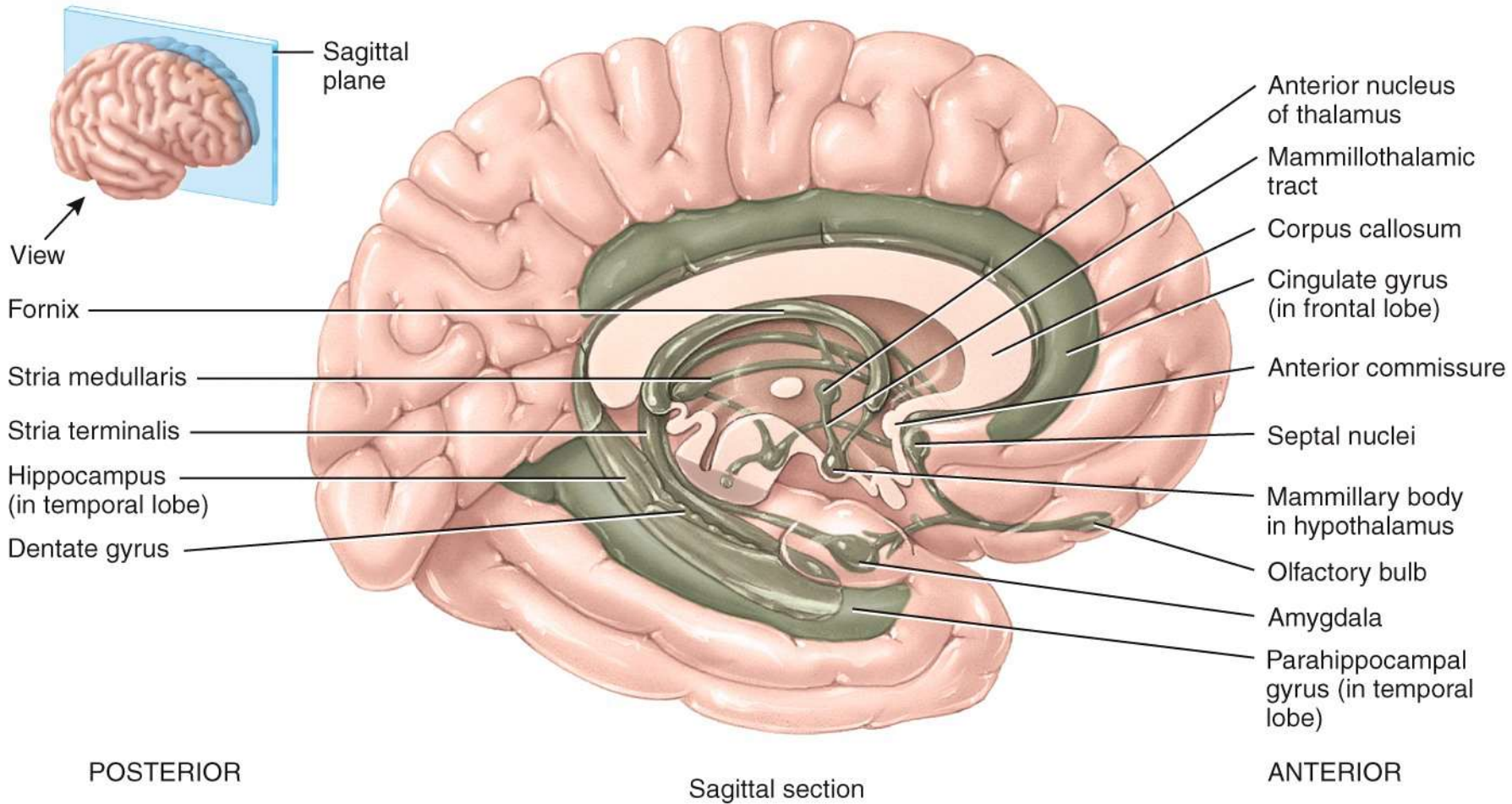


The limbic brain **processes innate emotions** (anxiety, fear, aggression, pleasure, empathy, etc) then was able to remember the experiences, and process these experiences as pleasant or unpleasant to create a **motivational system**. This helps to shape our behavioral (ie. subconscious judgment values) in response to new experiences from new stimuli based on **innate instincts and past experience that are remembered as either pleasant or unpleasant.**



# The Limbic System

## (The Paleo-Mammalian Formation)



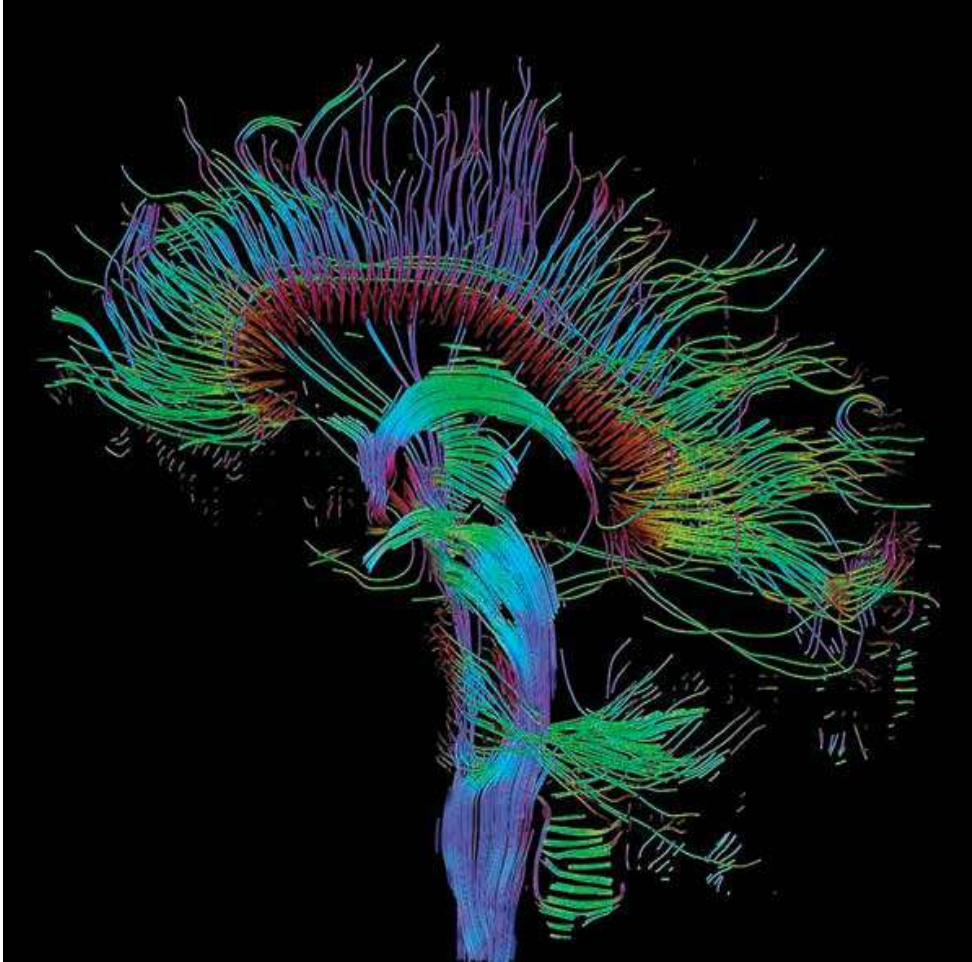
If you want to learn more about the structure and function of the limbic system then go to the links to Dr. Robert Sapolsky's videos on my Web site's Home Page.



The **neocortex** (also called **Neomammalian formation**) first became significant in whales, primates and reaches it highest development in the human brain. Two large cerebral hemispheres are the dominate structures of the neocortex. This is the location responsible for development of human language, abstract thought, imagination, and consciousness. The neocortex is flexible and has almost infinite learning abilities .

The neocortex is also the location for our Declarative Knowledge. This is the knowledge we learn from the world that we live in. It is knowledge derived especially from sight, sound and touch. The neocortex declarative knowledge is most developed in humans. Without a neocortex, we would not have a culture. We have two distinct types of knowledge: procedural = knowing how VS declarative = knowing what.

These three parts of the brain are still functional in today's human brain. They do not operate independently but have established **numerous interconnections between the three formations and influence one another**.



Human brain showing nerve tracks that connect the three brain formations.

So now we can understand how the unconscious emotional brain of the limbic system is able to make our value judgments, and then send them to our prefrontal cortex which then processes our conscious thoughts (note: the medial orbitalfrontal cortex makes conscious decisions based on outcomes which are based on expected rewards and punishments. The MOFC plays an important role in adaptive learning.

Neural pathways between the limbic system and the MOFC compete to shape the outcome of our experiences. (E.g. - Will you throw your drink into your bosses' face because you don't like your boss?)

How may the emotional brain cripple the neocortex? Will the experience leave you paralyzed in fear and anxiety? Or are you left with rage and then fight to your death?





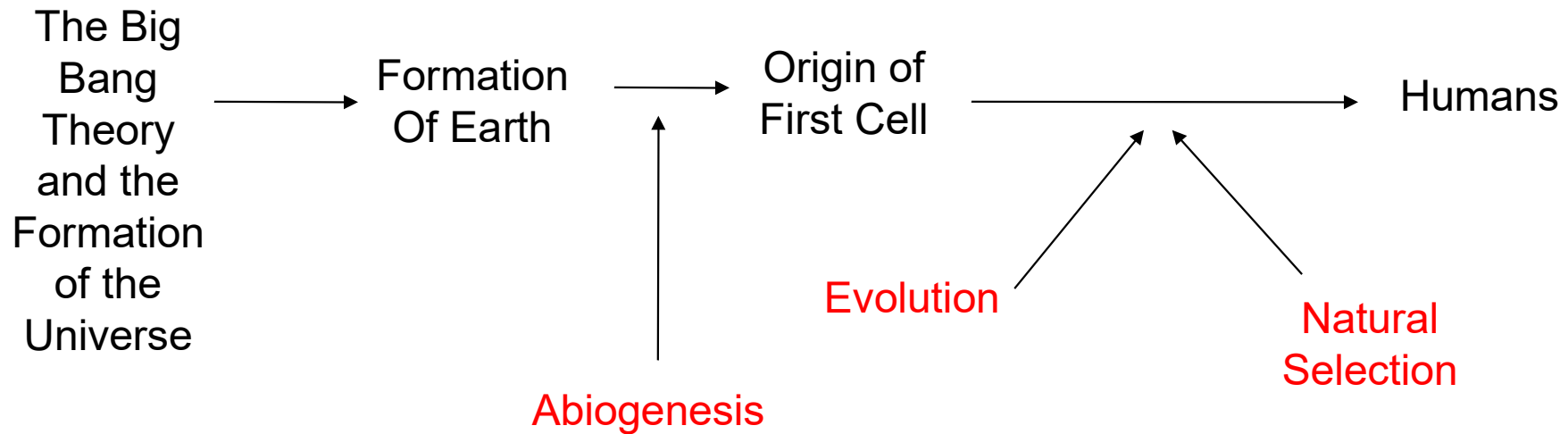
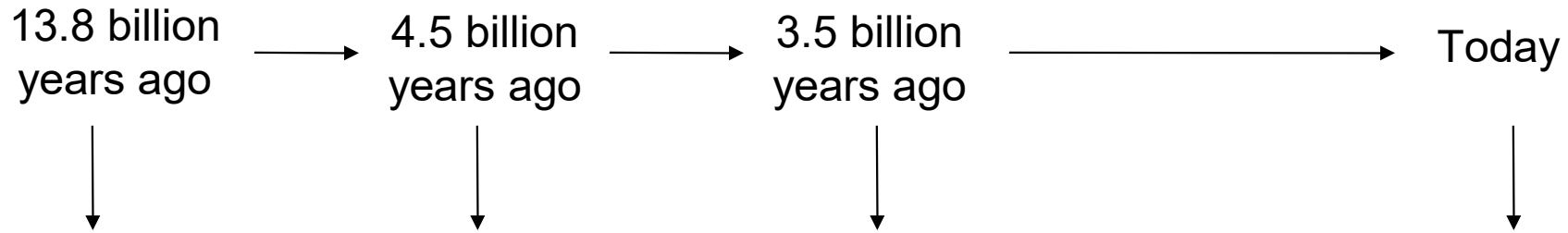




# The Forces That Created Life

## *Physics – Chemistry - Time*

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# Key Steps in Evolution of Humans from Single Cell to Today

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- 13.8 billion years ago (bya) // universe formed (The Big Bang Theory)
- 4.5 bya // earth formed
- 3.5 bya // It took 1 billion years for earth's molten rock to cool and for comets striking earth to fill the oceans with water // period of abiogenesis
- 3.5 bya // first fossil evidence for prokaryotic cells
- 2.5 bya // endosymbiosis
- 2 bya // first fossil evidence for eukaryotic cells
- 2 bya // three domains exist // bacteria – archaea- eukaryotes
- 2 bya // *Grypania spiralis* - first multicellular organism
- 540 – 488 mya // Cambrian Period (Explosion)
- 500 mya // First fish
- 350 mya // insects and plants on land
- 300 mya // First reptiles
- 250 mya // First mammals // First dinosaurs
- 225 mya // First mammals // First dinosaurs
- 85 mya // First primates ←
- 65 mya // KT Extinction // mass extinction of dinosaurs
- 65 mya // divergence of the primate family tree
- 40 mya / divergence of old world and new world monkeys
- 7 mya // divergence of gorillas and chimpanzees
- 6 mya // divergence of chimpanzees and *Ardipithecus ramidus* (would lead to hominids)
- 4 mya // *Australopithecus anamensis*
- 2 mya // *Australopithecus afarensis* (Lucy)
- 1.75 mya // *Homo habilis* // first hominid
- 1.5 mya // *Homo erectus*
- 750,000 – 40,000 yr ago // *Homo neandertalensis*
- 200,000 years ago // *Homo sapiens* // Today, we are the only surviving hominid, that's us!



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*Note: Dates are approximate to reference significant evolutionary events. Some events occurred over millions of years and many events co-existed with extended periods of overlap.*



**TARSIERS ARE UNIQUE PRIMATES.** Tarsiers are a unique group of primates, an intermediate form between lemurs and monkeys. While they are classified in the suborder Haplorhini with monkeys and apes, making them more related to them than to lemurs, they occupy their own intra-order, Tarsiiformes.

The divergence that led to the tarsiers probably dates to about 55 million years ago. The earliest tarsier-like fossils are found at that time in East Asia.

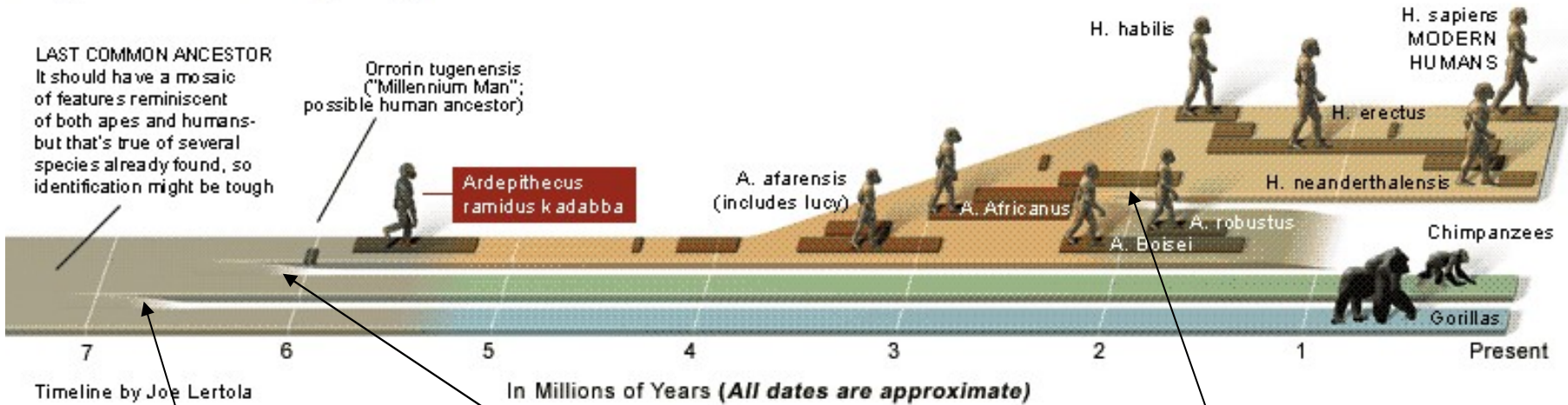


(Note: first primates 85 mya)

Over periods of millions of years different populations of hominids co-existed primarily throughout Africa

## A WALK THROUGH HUMAN EVOLUTION

The newest fossils have brought scientists tantalizingly close to the time when humans first walked upright—splitting off from the chimpanzees. Their best guess now is that it happened at least 6 million years ago



Gorillas and Chimpanzees Divergence

Chimpanzees and Proto-hominids Divergence

Australopithecus and Homo Divergence

- **For more information about the Triune Brain Theory see [www.mc3cb.com](http://www.mc3cb.com)**
  - **Go to the Archival Articles hyperlink / see brain reference articles / Triune Theory**