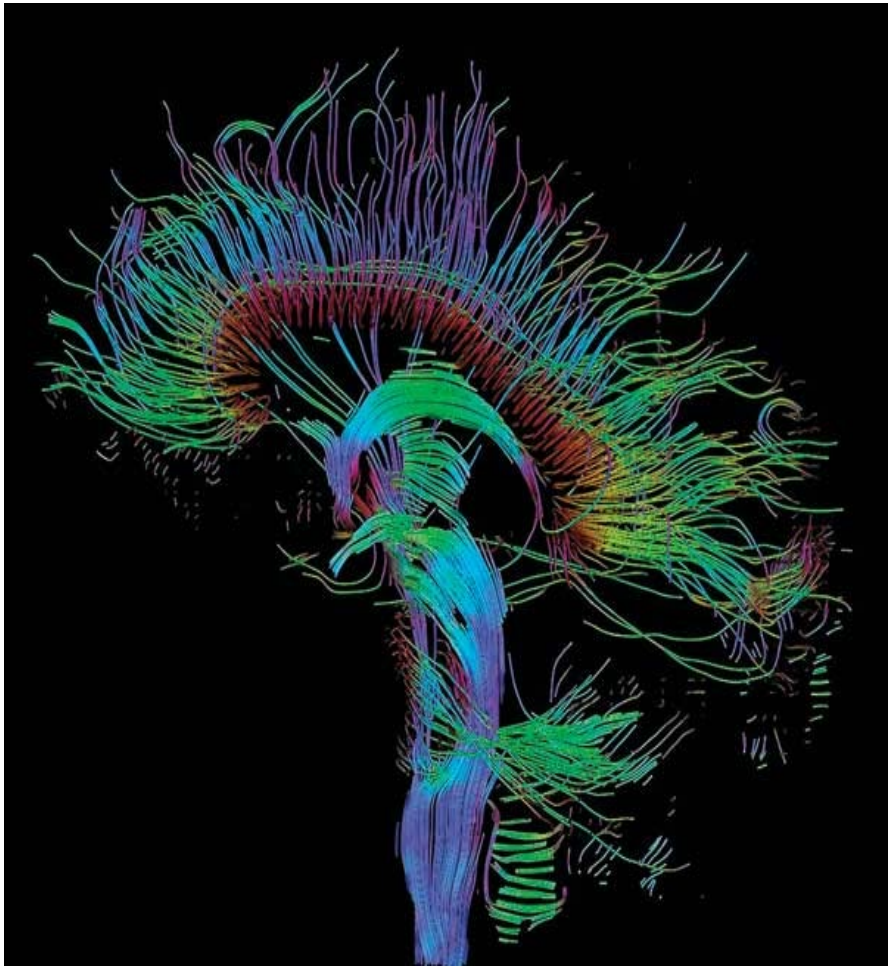
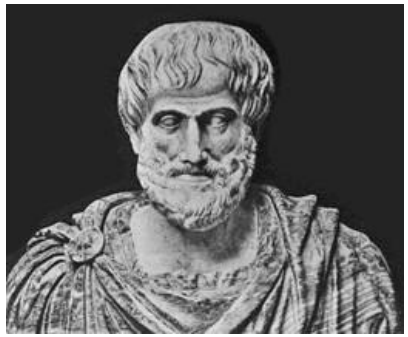
Chapter 14.1

Brain Evolution



What Greek Philosophers And What They Thought About the Brain

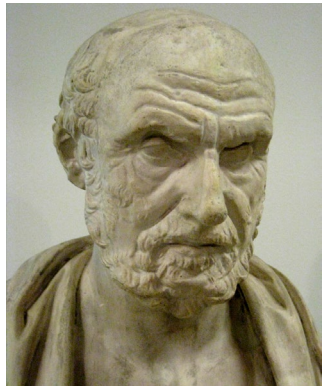
Aristotle (384 BCE) - Stagira, Greece // Philosopher (scientist)



Thought the brain was a ‘radiator’ to cool blood

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.

Hippocrates (460 BCE) - Kos, Greece – Philosopher (scientist)



From the brain only, arises our pleasures, joys, laughter, and jests, as well as our sorrows, pains, griefs, and tears”

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.

The Hippocratic Oath is an ancient code of ethics for physicians, requiring new doctors to uphold high ethical standards in their practice, prioritize patient welfare, and maintain confidentiality.

Today we define the cessation of brain activity as the clinical criterion of death

The Evolution of the CNS

First vertebrae (fish) occurred about 550 million yrs ago // Spinal cord changed little throughout vertebrate evolution

The brain has changed a great deal over the last 20 million years.

Greatest growth and change 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!

Triune Brain Theory – metaphor to help us understand how the human brain developed as three distinct "layers" // occurred over millions of years

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

The modern brain evolved in three evolutionary stages also referred to as brain formations.

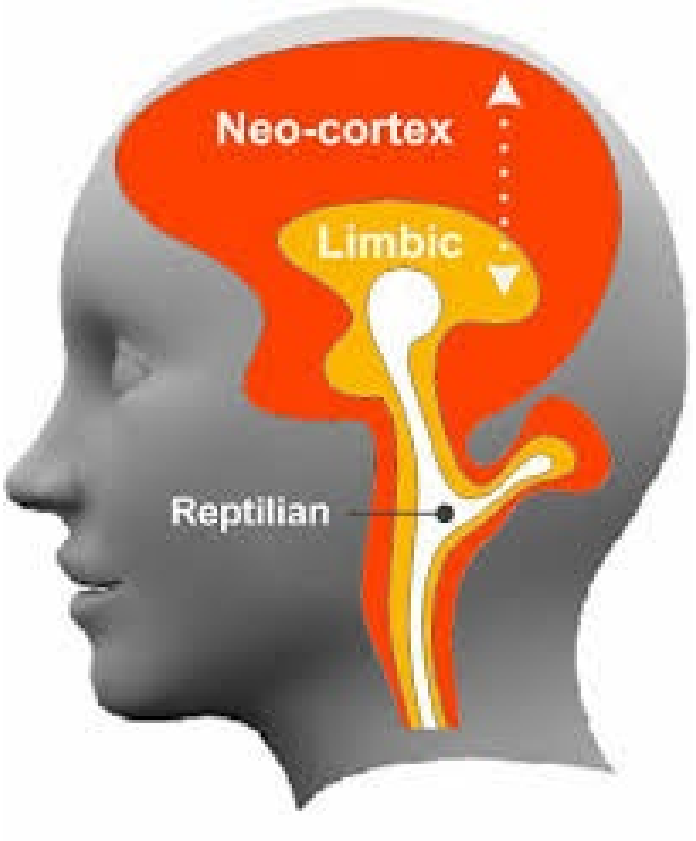
Each formation existed for relatively long stable periods (over 100's of millions of years) followed by the gradual development of the next formation.

This pattern existed throughout the evolution of the vertebrate brain.

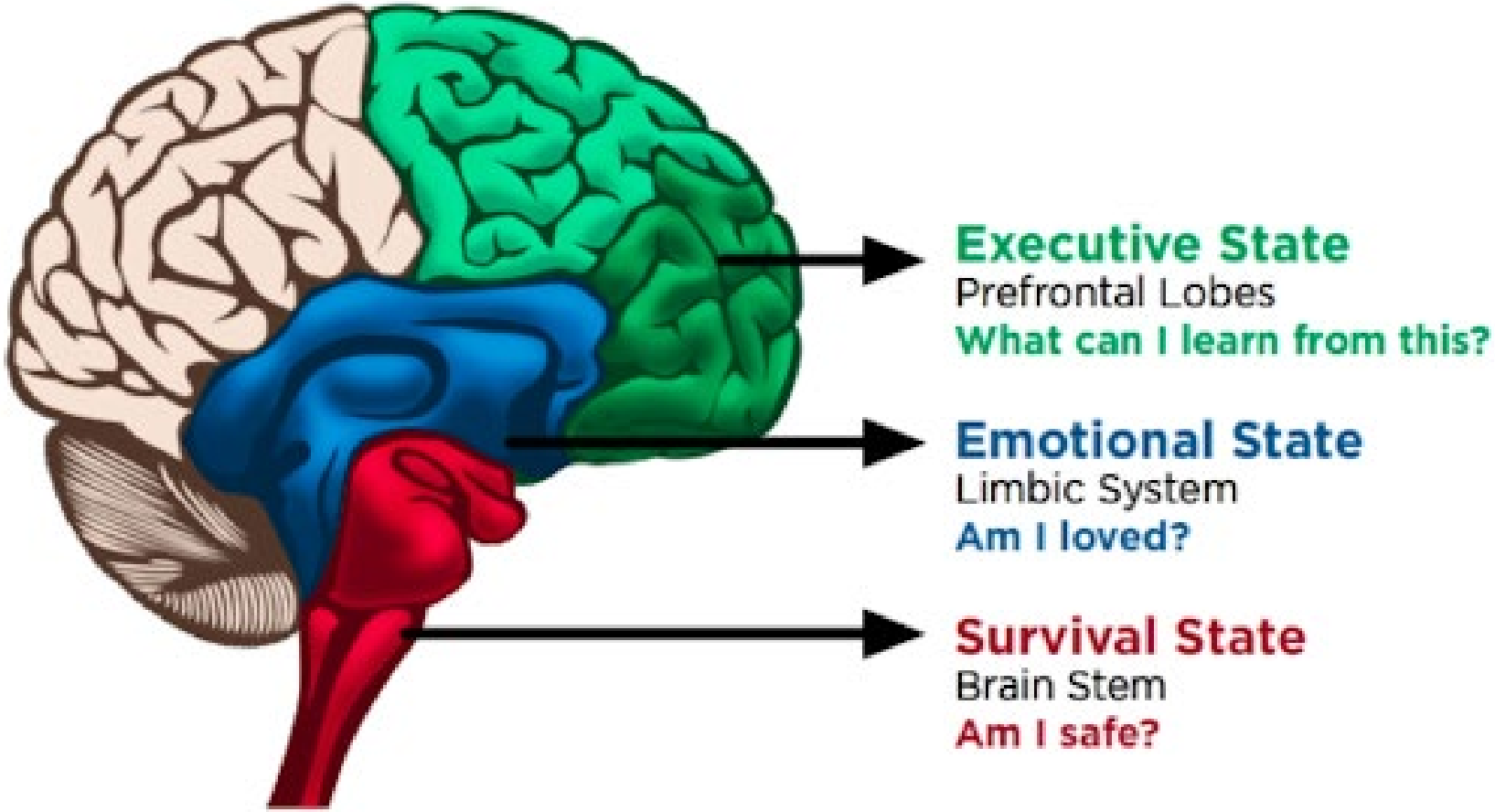
These are the “Three Brain Formations”

- –Protoreptilian Brain Formation
- –Paleomammalian Brain Formation (Limbic System)
- –Neomammalian Brain Formation (Neocortex)

Triune Brain Theory



Triune Brain Theory



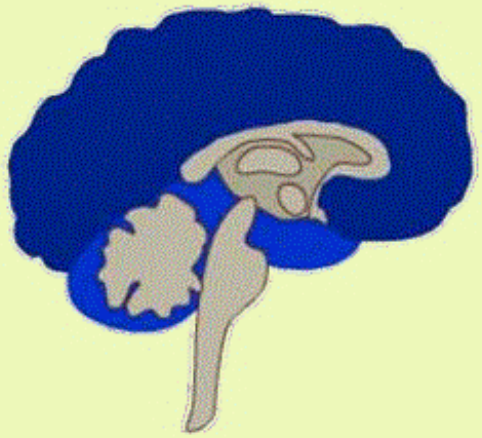
The Three-Parted Brain

Lizard Brain
(Brain stem and cerebellum)

Autopilot
Fight & Flight

Mammal Brain
(Limbic System)

Emotions
Memories
Habits
Attachments



Human Brain
(Neo-Cortex)

Language, abstract thought, imagination, consciousness, reasoning, rationalising

(From Paul D. MacLean's model of the "Triune Brain")

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** develop 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. (315 MYA)

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, perdictable, 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!

Paleomammalian Formation (Limbic System)

The **Paleomammalian formation** **(also called the limbic brain)** emerged with the first "stem mammals" (over 225 mya).

For the first time, ***emotional instincts were encoded as innate structural entities*** (What is a nuclei?).

First time stem mammals *developed the ability to* ***remember innate emotional experiences as either being agreeable or unagreeable (pleasant or unpleasant).***

Not conscious but the location of our values.

These memories help to shape the behavior of mammals in terms of their experience. Today, we think of the limbic system as our emotional brain.

Better to think of the limbic system as our survival brain and our fast brain. But these nuclei also plays a part in how we make decisions based on our "values".

When you are in a stressed state, have you ever said, "I don't know but I am going with my gut feeling"? This occurs when you let the limbic system make the decision because you don't have the energy to operate your "slow brain".

Paleomammalian Formation

(Limbic System)

The limbic system is a collection of nuclei that are all “inter-connected. (They can talk to each other.”

The main structures of the limbic brain are the hippocampus, the amygdala, and the hypothalamus (other interconnected structures include parts of the thalamus, nucleus accubens, septal nuclei, mammillary bodies, and other structures.)

Best described as a limbic lobe located deep within the cerebrum.

The limbic brain is the location of our value judgments. These are decisions that are made as part of our subconscious brain activity.

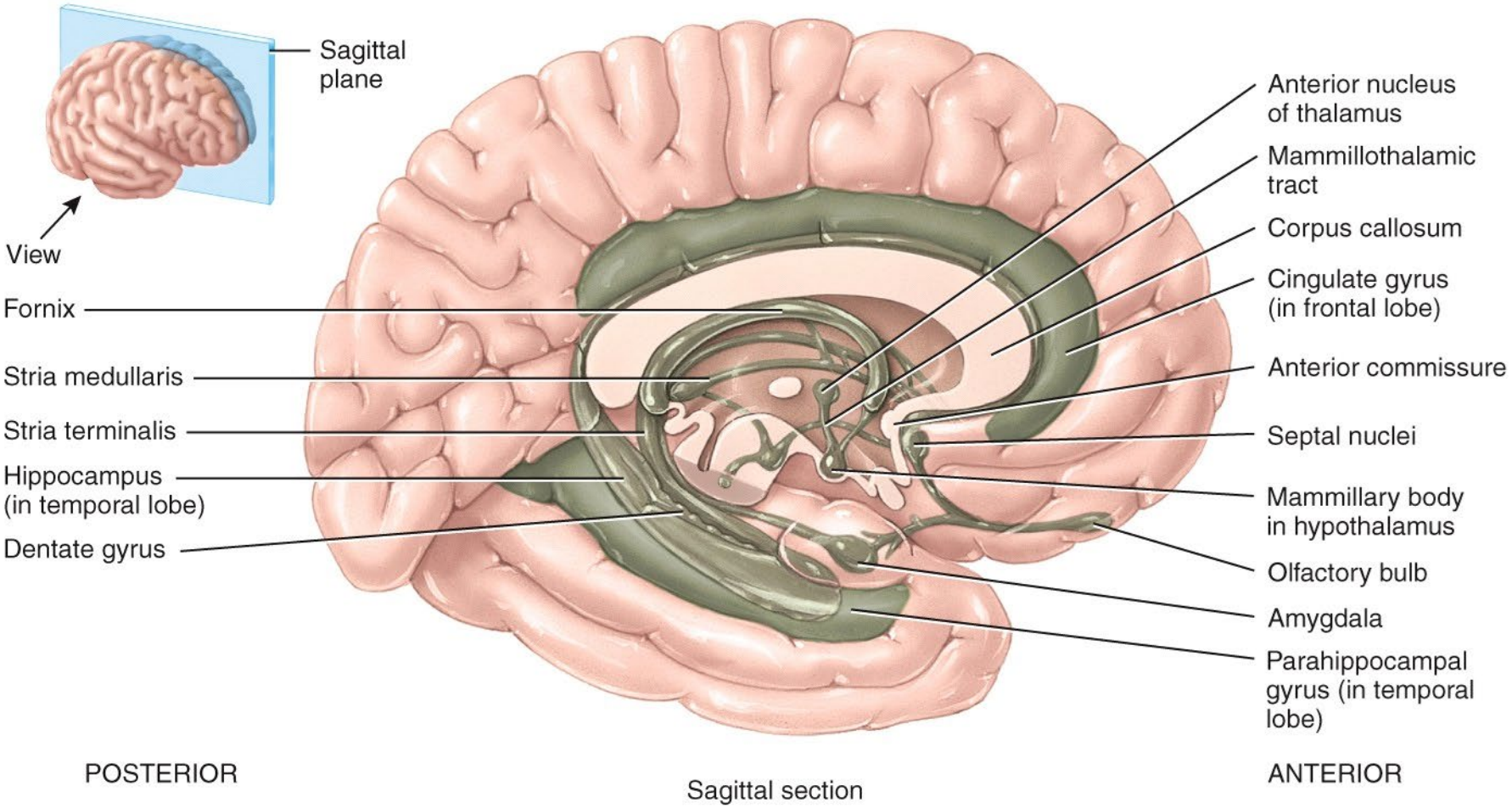
The limbic system exert a strong influence on our conscious behavior because nerve tracts connect the limbic system to the neocortex with bidirectional signaling.

The limbic brain processes innate emotions (anxiety, fear, aggression, pleasure, empathy, etc) tand remember the experiences as pleasant or unpleasant to create a value, judgement, survival and motivational system .

The limbic system's shapes our behavioral by comparing somatosensory stimuli to limbic innate instincts and experience. The subconscious brain (fast brain but not very accurate) has great influence on the conscious brain (slow brain but slow and requires a lot of energy).

The Limbic System

(The Paleo-Mammalian Formation)



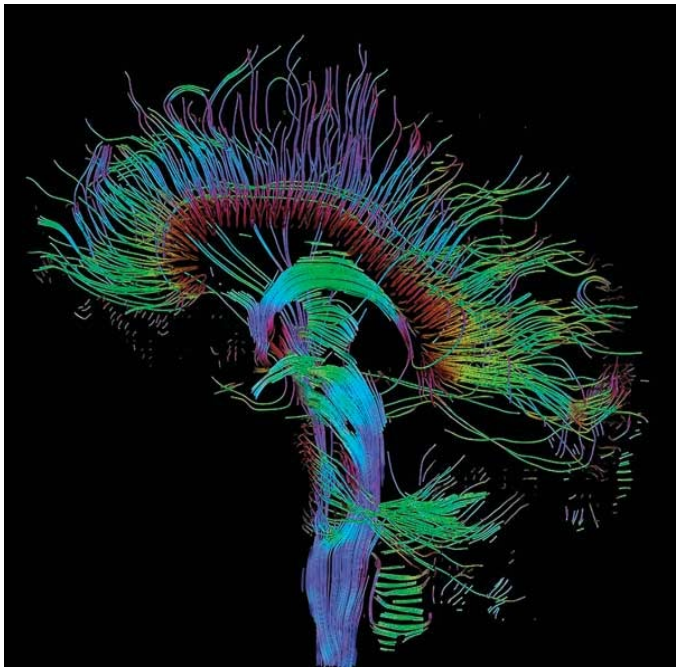
If you want to learn more about the structure and function of the limbic system then go to the link to Dr. Robert Sapolsky's videos on my Web site's Home Page.

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 . (first animals with neocortex 200 mya)

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.

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



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

We understand how the unconscious emotional brain of the limbic system may influence the decisions we make. We also know how the neocortex may influence our reptilian brain. Think about psychosomatic diseases!

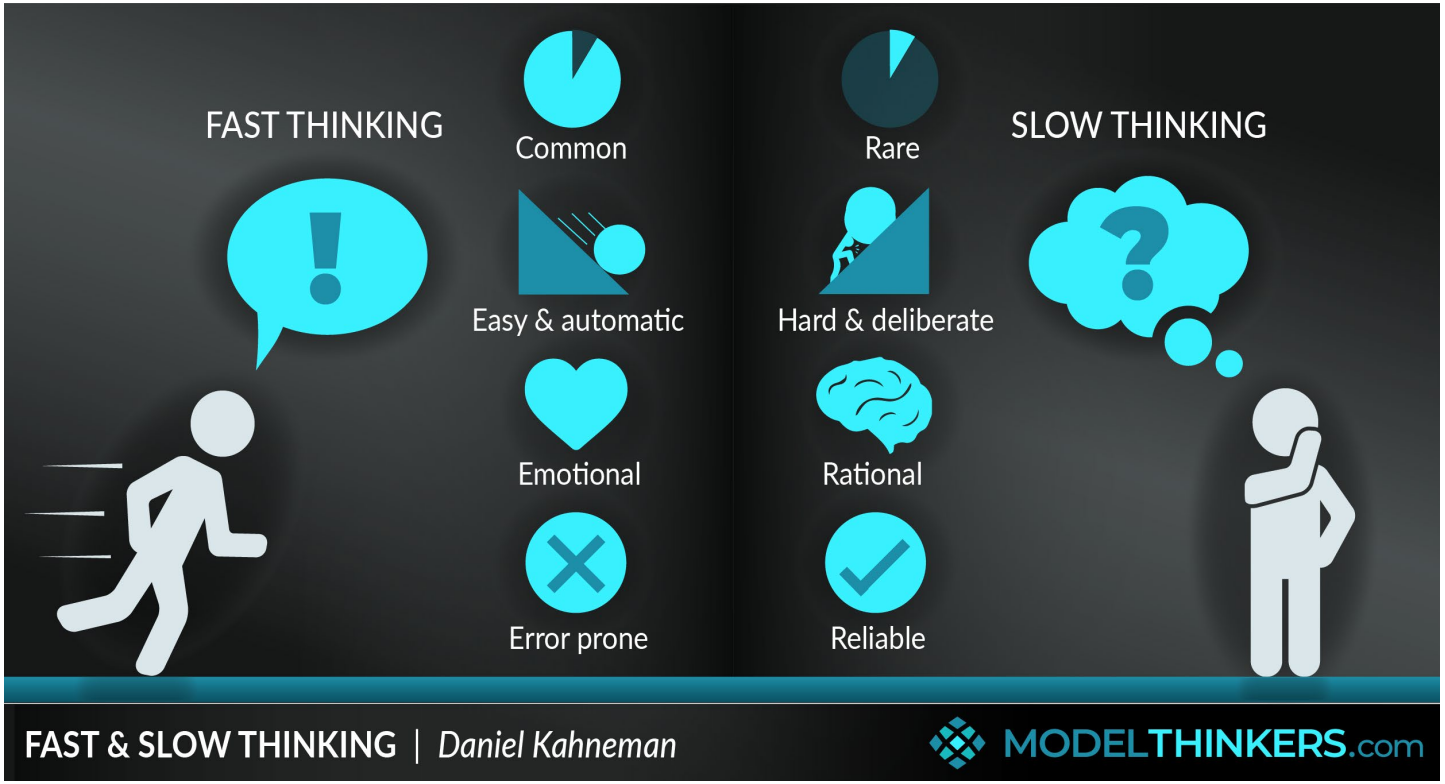
The amygdala (limbic structure) is connected to the medial orbital frontal cortex (neocortex). The MOFC makes conscious decisions based on analysis based on expected rewards vs punishments. The limbic system may send signals to the MOFC to influence the decision making of the neocortex.

The MOFC plays an important role in adaptive learning.

Neural pathways between the limbic system and the MOFC/neocortex compete to shape the outcome of our experiences.

At times, the emotional brain may dominate over the neocortex. This occurs when you are under stress, tired, not prepared for a test, or hungry.

The limbic system is the fast brain, and the neocortex is the slow brain. It takes a lot more effort (energy) to use the slow brain. The fast brain is easier to use (less energy) but more likely to be wrong!

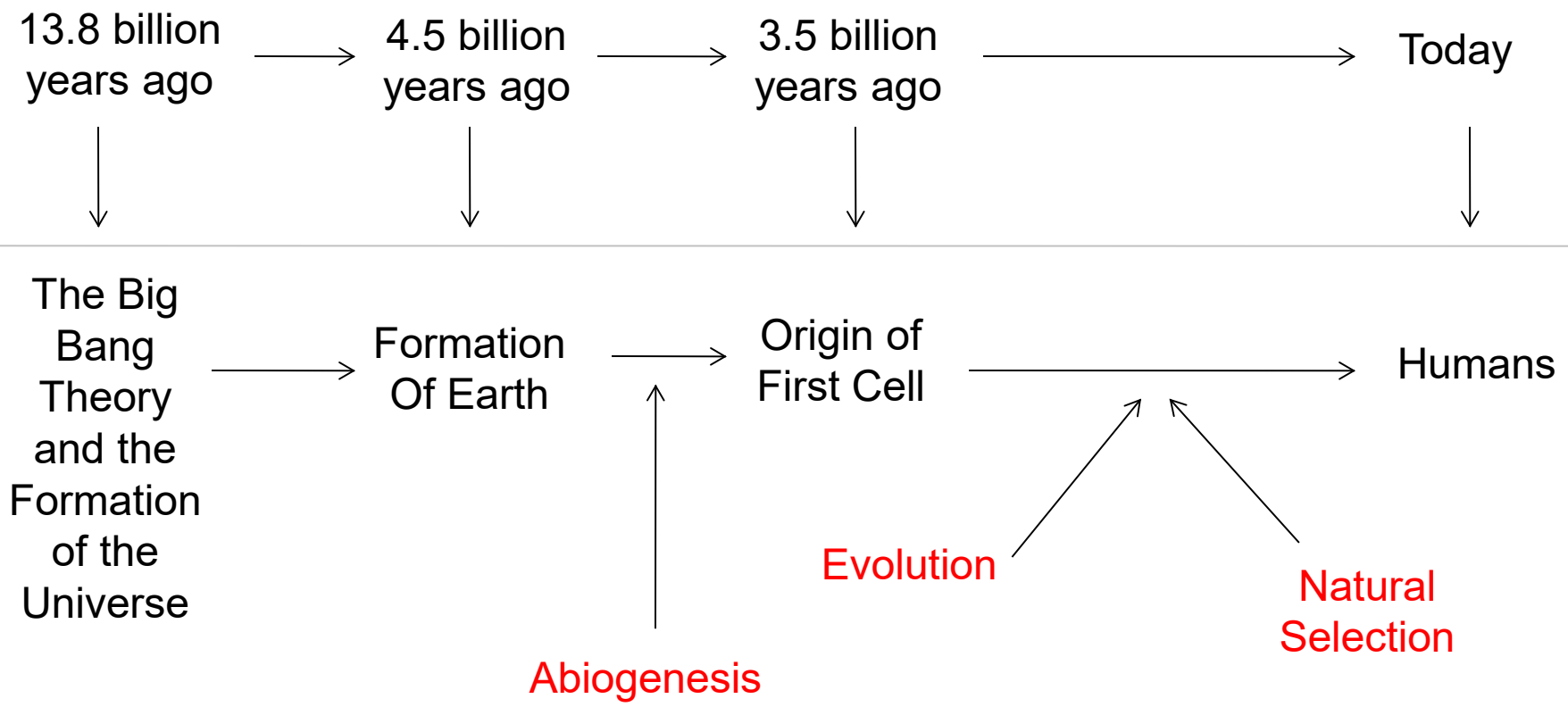


We share over 99% of the same genes.

We did not evolve from chimpanzees. However, we did share a “common ancestor”.
Six million years ago, we diverged from our common ancestor
and then we both followed our own evolutionary pathway.

The Forces That Created Life

Physics – Chemistry - Time



Key Steps in Evolution of Humans from Single Cell to Today

- 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 abiogenisis
- 3.5 bya // first fossil evidence for prokaryotic cells
- 2.5 bya // endosymbiosis
- 2 bya // first fossil evidence for karyotic cells
- 2 bya // three domains exist // bacteria – achaea- 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 Ardipethicus ramidus (would lead to hominids)
- 4 mya // Australiopithecus 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 neandethalensis
- 200,000 years ago // Homo sapiens // Today, we are the only surviving hominid, that's us!

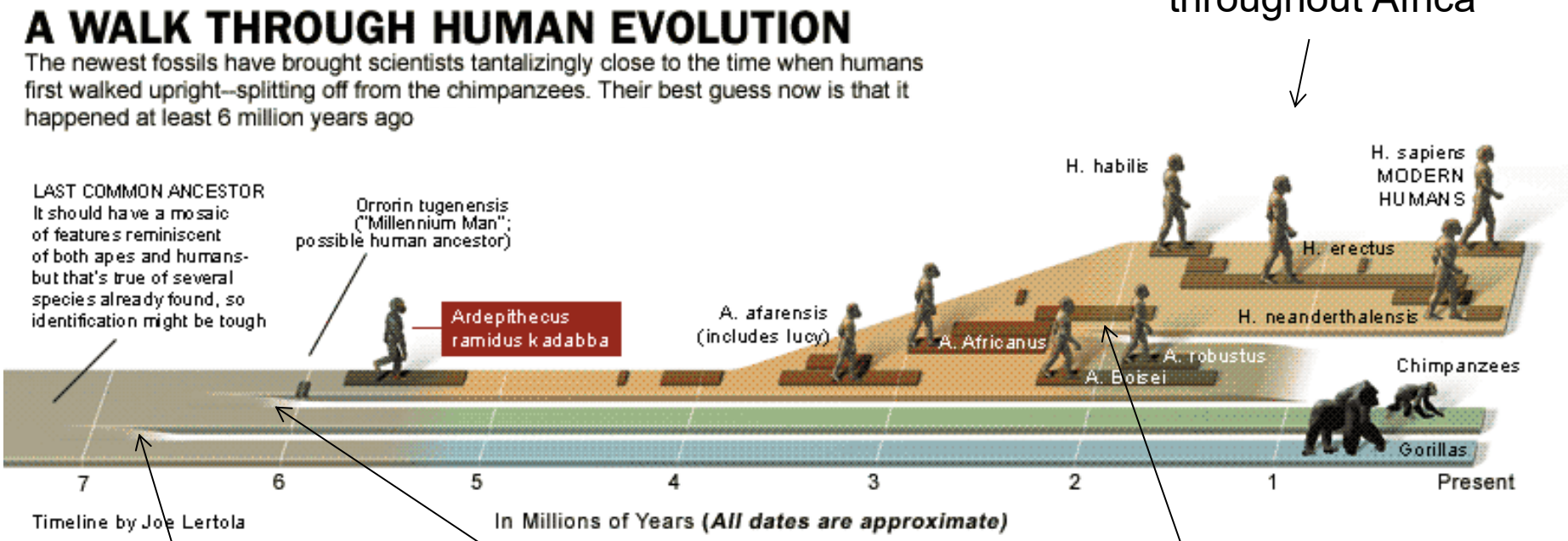
Note: Dates are approximate to reference significant evolutionary events. Some events occurred over millions of years and many events co-existed with extended periods of overlap.

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



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**

  – **Go to the Archival Articles hyperlink / see brain reference articles / Triune Theory**