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THE EVOLUTIONARY LAYERS OF THE HUMAN BRAIN

The first time you observe the anatomy of the human brain, its many folds and overlapping structures can seem very confusing, and you may wonder what they all mean. But just like the anatomy of any other organ or organism, the anatomy of the brain becomes much clearer and more meaningful when you examine it in light of the evolutionary processes that created it.

The most efficient model for understanding the brain in terms of its evolutionary history is the famous triune brain theory developed by Paul MacLean. According to this theory, the following three distinct brains emerged successively in the course of evolution and now co-inhabit the human skull:

The **reptilian** brain, the oldest of the three, **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**. The reptilian brain is reliable but tends to be somewhat rigid and compulsive.

The **limbic** brain emerged in the first mammals. It can record memories of behaviors that produced agreeable and disagreeable experiences, so it is **responsible for what are called emotions in human beings**. The main structures of the limbic brain are the hippocampus, the amygdala, and the hypothalamus. The limbic brain is the seat of the value judgments that we make, often unconsciously, that exert such a strong influence on our behaviour.

The **neocortex** first assumed importance in **primates and culminated in the human brain** with its two large cerebral hemispheres that play such a dominant role. These hemispheres have been responsible for the development of human **language, abstract thought, imagination, and consciousness**. The neocortex is flexible and has almost infinite learning abilities. The neocortex is also what has enabled human cultures to develop.

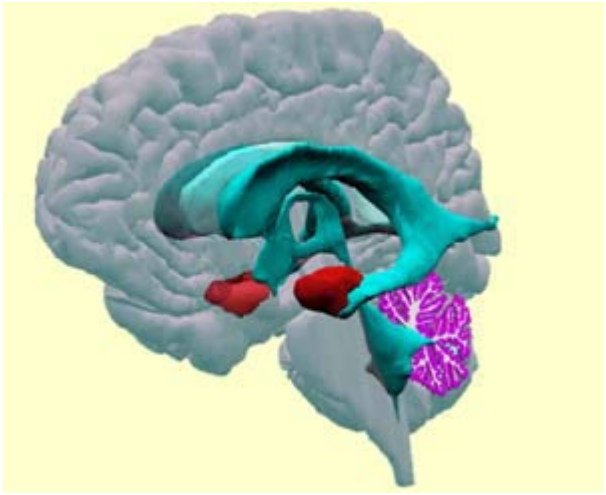
These **three parts of the brain do not operate independently of one another**. They have established **numerous interconnections** through which they influence one another. The neural pathways from the limbic system to the cortex, for example, are especially well developed.

THE AMYGDALA AND ITS ALLIES

The **amygdala** is an almond-shaped structure in the brain; its name comes from the Greek word for “almond”. As with most other brain structures, you actually have two

amygdalae (shown in red in the drawing here). Each amygdala is located close to the hippocampus, in the frontal portion of the temporal lobe.

Your amygdalae are essential to your ability to feel certain emotions and to perceive them in other people. This includes fear and the many changes that it causes in the body. If you are being followed at night by a suspect-looking individual and your heart is pounding, chances are that your amygdalae are very active!



In certain studies, researchers have directly stimulated the amygdalae of patients who were undergoing brain surgery, and asked them to report their impressions. The subjective experience that these patients reported most often was one of imminent danger and fear. In studies of the very small number of patients who have had had only their amygdala destroyed (as the result of a stroke, for example), they recognized the facial expressions of every emotion except fear.

In fact, the amygdala seems to modulate all of our reactions to events that are very important for our survival. Events that warn us of imminent danger are therefore very important stimuli for the amygdala, but so are events that signal the presence of food, sexual partners, rivals, children in distress, and so on.

That is why the amygdala has so many connections with several other structures in the brain.

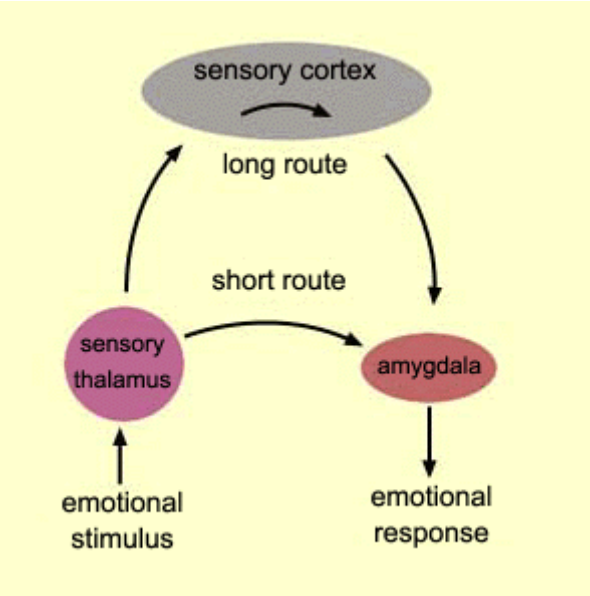
THE TWO PATHWAYS OF FEAR

The amygdala lets us react almost instantaneously to the presence of a danger. So rapidly that often we startle first, and realize only afterward what it was that frightened us. How is this possible?

It all has to start, of course, with a sensory stimulus, such as a strange shape or a menacing sound. Like all information captured by the senses, this message must be routed first to the thalamus. The thalamus then sends this message on to the appropriate

sensory cortex (visual cortex, auditory cortex, etc.), which evaluates it and assigns it a meaning. If this meaning is threatening, then the amygdala is informed and produces the appropriate emotional responses.

But what has been discovered much more recently is that a part of the message received by the thalamus is transferred directly to the amygdala, without even passing through the cortex! It is this second route, much shorter and therefore much faster, that explains the rapid reaction of our natural alarm system.



Since everything has a price, this route that short-circuits the cortex provides only a crude discrimination of potentially threatening objects. It is the cortex that provides the confirmation, a few fractions of a second later, as to whether a given object actually represents a danger. Those fractions of a second could be fatal if we had not already begun to react to the danger. And if the cortex turns out to advise us that there is nothing to worry about after all, we have merely had a good scare, and that is it.

Children have less control over their emotions, because the axons that send information from the cortex to the limbic system are not yet fully developed. In addition, the neurons of the prefrontal cortex that provide much of our rational control over our emotions do not mature until early adulthood. In contrast, the amygdala is mature at birth and thus exerts a heavy influence on children.

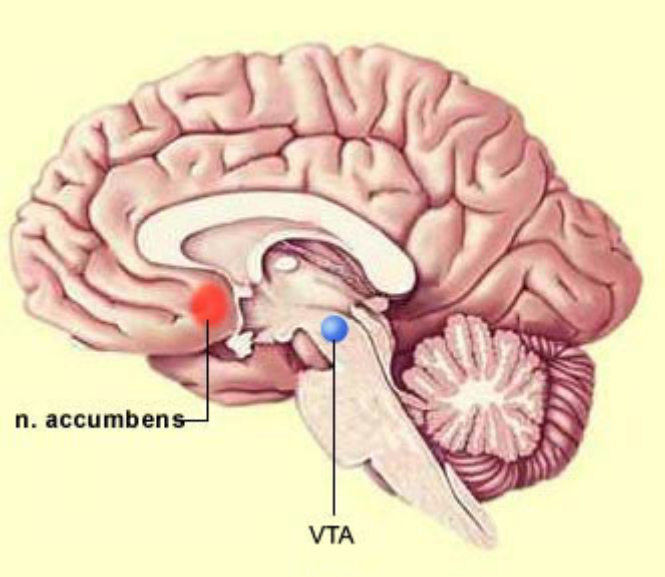
Emotions are something that happens to us much more than something we decide to make happen. Much of the explanation for this lack of direct control over our emotions lies in the way that the human brain is interconnected. Our brains have evolved in such a way that they have far more connections running from our emotional systems to our cortex (the locus of conscious control) than the other way around.

In other words, the noise of all the heavy traffic on the major highway running from the limbic system to the cortex masks the quieter sounds on the little road running in the other direction.

THE PLEASURE CENTRES

For a species to survive, its members must carry out such vital functions as eating, reproducing, and responding to aggression. Evolution has therefore developed certain areas in our brain whose role is to provide a pleasurable sensation as a "reward" for carrying out these vital functions.

These areas are interconnected with one another to form what is known as the "reward circuit".



The ventral tegmental area (VTA), a group of neurons at the very centre of the brain, plays an especially important role in this circuit. The VTA receives information from several other regions that tell it how well various fundamental needs, and more specifically human needs, are being satisfied.

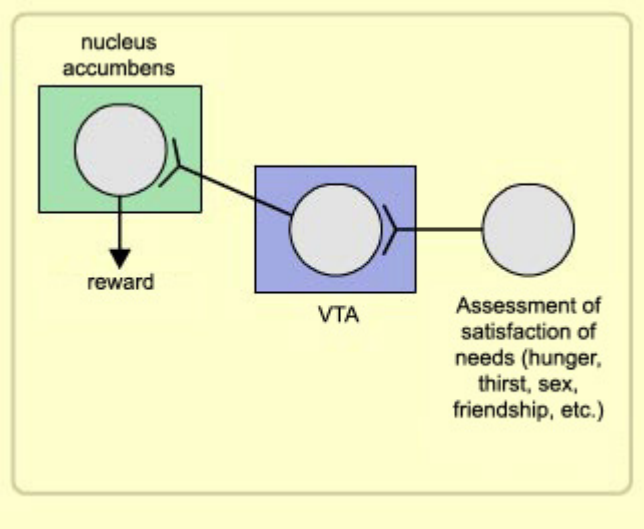
The VTA then forwards this information to another structure further forward in the brain: **the nucleus accumbens**. To send this information to the nucleus accumbens, the VTA uses a particular chemical messenger: dopamine. The increase in the level of dopamine in the nucleus accumbens, and in other brain regions, reinforces the behaviours by which we satisfy our fundamental needs.

THE REWARD CIRCUIT

Eating, drinking, having sex, and displaying maternal behaviour are all activities that are essential for the survival of the individual and the species. In the course of evolution, natural selection has associated strong feelings of satisfaction with these behaviours that meet such basic needs. A veritable reward circuit evolved to encourage these behaviours. Subsequently, this circuit expanded to encourage us to repeat other pleasurable experiences that we learn in the course of our lives.

The reward circuit is at the heart of our mental activity and guides all our behaviors. This circuit is complex, but it contains a central link that seems to play a fundamental role.

This link consists of the nerve connections between two particular small groups of neurons. One of these groups is located in the ventral tegmental area (VTA), and the other in the nucleus accumbens.



The chemical messenger that makes the connections between these two groups of neurons is dopamine. This is the site where most drugs act and cause dependencies.