Neuroscience for Business

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The brain and the neurosciences may be an unexplored field for many readers and so we aim in this chapter to jump into some of the specifics of the brain: to understand how it develops, how it functions and what this means for us. We will start with a very brief history of neuroscience before moving into the brain and its formation and functioning. We will then throw a spotlight on the technology that is driving the research before moving in to some specifics of brain functions that have a key impact on business and how we operate.

Objectives

– Understand the different fields in neuroscience
– Provide an overview of the technologies behind the research
– Understand the brain's structure
– Introduction to key biological substrates of the brain
– A basic functional understanding of the brain and impact on business contexts

2.1 Introduction

The neurosciences are far-reaching and interdisciplinary in their nature. Indeed, they need to be if they want to look into the functioning of the nervous system as a whole. This includes the biology but also the psychology and not forgetting the body itself. Neuroscientists need to be thinking at a molecular level but also at a human behavioural level. There have been massive steps in the neurosciences in recent years and our knowledge of the brain has made huge leaps forward and this has also opened the doors for wider applications in and out of the laboratory meaning that many disciplines now come under the umbrella of the neurosciences. This chapter serves to give an overview and introduction to the neurosciences and the brain.

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2.2 Neuroscience: its Development and its Disciplines

2.2.1 A Very Brief History of Neuroscience

The history of neuroscience in many ways is linked tightly to the history of medicine but also to perceptions of man: the idea that our consciousness could sit in an organ was anathema to many religions.

Trepanation, the act of boring or scraping a hole in the skull to relieve pressure due to damage, has been found in many Neolithic cultures (Heidecker 2006) and is still practised in some remote tribes in Africa. Some knowledge of brain damage has been recorded by Egyptians dating back to 1700 BC (Kandel et al. 2000). However, the predominant view in the ancient world was that the heart was the source of consciousness though Hippocrates challenged this noting the proximity to the sensory organs. Aristotle was unconvinced and still espoused the heart as the seat of consciousness and the brain as simply a cooling mechanism for blood. It was only Galen a Roman physician who noted the effects of a damaged brain on gladiators. Galen himself was a skilled surgeon—many of his techniques would not be used until centuries later and some are precursors to today's operations (for example his cataract operations). His "squealing pig operation" was likely the first experimental evidence that the brain is connected to action (Gross 1998).

Further advances were made in the Middle Ages with ever increasing skills of surgeons and the continual study of dissections. Some names in the brain, the hippocampus, for example, date back to this era (Gurunluoglu et al. 2011).

The well-known case of Phineas Gage in 1848, though it is in actuality poorly documented, showed that there were potentially regional functions in the brain linked to personality disorders (Bigelow and Barnard 2002). This had been proposed by Gall in the eighteenth century (but discredited by many including the Roman Catholic Church who thought that God creating a physical seat of the mind, which was God-given, as being an anathema) (Gall and Spurzheim 1810). Phineas Gage was a foreman working on railroad construction and in a bizarre accident a metal rod was blasted through his head—under his cheek bone, taking out his right eye and up through the front part of the skull. He survived, miraculously, and recovered, but apparently suffered severe personality disruptions. Around this period there was more research from physicians such as Broca and Wernicke whose study of patients with tumours led them to identify two different areas involved in language production and language comprehension respectively.

Neuroscience, however, took a large step forward with the development of the microscope and at the turn of the twentieth century Cajal's study of neurons using Golgi's method of staining tissue using silver nitrate—this is still the base of various tissue staining techniques used to this day—led to the first pictorial representations of neurons (Jones 2007). Cajal detailed diagrams of neurons led to the development of the theory of the neuron—the neuron as the base for interactions in the brain (Tixier-Vidal 2010).

At the same time it was also proposed that neurons were electrically excitable. The localization theory was further supported by the work of John Hughlings

Jackson whose work into epilepsy patients led him to correctly infer the organisation of the motor cortex. Brodmann published his map of the brain in 1909 (Brodmann 1909; Loukas et al. 2011) labelling different areas. His numbered areas are still used today e.g. Brodmann area 4 is the primary motor cortex.

In 1952 Andrew Huxley first proposed a mathematical model for the electrical currents, action potentials, in neurons (Hodgkin and Huxley 1952) and in 1962 the transmission across synapses—between neurons—was first modelled by Bernhard Katz (Cowen & Kandel 2001). Eric Kandel's famous work into memory started in 1966 and from this time we saw neuroscience as an ever-expanding field.

The 1980s saw more popular books such as Oliver Sacks' "The Man who Mistook is Wife for a Hat" (Sacks 1985) bringing brain disorders into the public spotlight. With the advent of imaging technologies in the 1980s and 1990s (the 1990s were also declared the decade of the brain which stimulated substantial government funding, particularly in the USA) the research has mushroomed with ever increasing fields also looking into the brain. This is not least also driven by major pharmaceutical companies taking a great interest with the rise of disorders such as Alzheimer's, Parkinson's and dementia. We now have a mass of information and thousands of institutions with the latest technology looking into the brain at different levels and as this increases so does the funding and the technology. Though we have gained deep insights and made large steps in understanding, the brain's sheer complexity makes many processes still very elusive. Some claim we know enough to, for example, build a model of a brain in a computer (Blue Brain Project at EPFL in Lausanne (Blue Brain Project)[1], Switzerland) to simulate sicknesses and disorders and simulate the functions of drugs in the brain, others claim we have but scratched the surface.

But first let us look into what the neurosciences actually consist of, what the disciplines are.

2.2.2 Neuroscientific Disciplines

As we mentioned previously the neurosciences cover a large area and to the laymen these may sound similar and yet the differences for us are important. We will therefore now outline the terminology and formal disciplines in the neurosciences. Figure 2.1 represents an overview of these disciplines.

1. **Neurology**
   Neurology is the discipline of dealing with disorders of the nervous system and is a part of human medicine. This means specifically dealing with the diagnosis, therapy and prevention of sickness in the nervous system. This includes disorders in the central, peripheral and vegetative nervous system.
2. **Neurobiology**
   Neurobiology is the study of the structure, function and development of nerve cells and the nervous system. The term neurobiology is sometimes, however,

[1] http://bluebrain.epfl.ch/ Accessed 1 Nov 2012]

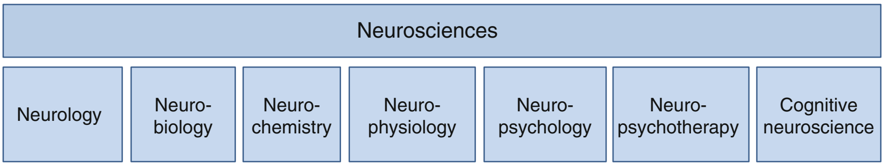

Fig. 2.1 Disciplines of neuroscience

used interchangeably with neuroscience whereby neurobiology is the specific study of the brain and its biological functions. Neuroscience is the broader science of the whole nervous system.

3. **Neurochemistry**
   Neurochemistry is the study of the chemical processes at a cellular level in the nervous system. The main focus is on the chemical transmitters in the synapses and the function of the receptors. The function of the neuroendocrine (hormone) system is also a key focus of neurochemistry.
4. **Neurophysiology**
   Neurophysiology is a sub-discipline of physiology and is the study of the performance and reaction of our nervous system to external stimuli. The focus is on the dynamic processes between nerve cells and how these process information.
5. **Neuropsychology**
   Neuropsychology is the study at the interface of psychology and the neurosciences. Here neuropsychologists will study behaviour in combination with neuroscientific technologies. For example, a decision-making task will also be analysed using brain scanning to identify which areas are activated in making specific choices. The goal is to connect behaviour to various brain regions and their specific processing and functions.
6. **Neuropsychotherapy**
   Neuropsychotherapy uses neuroscientific insights to treat psychological disorders. This is driven by the understanding that brain forms its view of the world through structural communication in the brain and that dysfunction in personality can also be represented by dysfunctions in the biology of the brain. The biology of the brain also shows that the brain is plastic and so new pathways and ways of behaving can be formed and reformed. In addition neuropsychotherapy aims to understand the chemical processes in the brain and how these manifest in different cognitive processes and are also biologically linked through the brain's ability to build respective receptors to these chemicals (see Sect. 2.9.1).
7. **Cognitive Neuroscience**
   Cognitive neuroscience deals with the neural substrates of cognition, of mental processes. They may include studying the neural mechanisms involved in attention, reward, memory and fear. Cognitive neuroscientists are instrumental in mapping the brain and its regions based on its cognitive functions.

This overview shows how many fields are included in the broad context of neuroscience and many of these overlap and indeed many research teams may have different specialists on the team. This is necessary as the brain is incredibly complex with a host of biological, chemical and cognitive processes all functioning in parallel to give rise to various psychiatric or nervous system disorders.

2.3 The Brain

The brain, it may seem obvious, plays a central role in the neurosciences. It is we note not the only focus as the central nervous system also includes all nerves in the body and there is also a growing body of research into embodied cognition: how thought can be grounded in the body and how the body can influence cognition—but for the purposes of this book we will not enter into this fascinating area. The brain we can see as the central processing unit of human beings. It is the seat of consciousness, of memory and hence also our feeling of "self" on top of our sensory and cognitive interaction with the world. The brain is therefore, in no short part, what we are. Its importance in the organism itself can also be seen by the amount of power and energy it uses:

Some facts and figures about the brain

- *The average human brain weighs* 1.3 *Kg and is 80 % water.*
- *The brain is only 2 % of body weight but uses up to 25 % of the body's energy resources (water, oxygen and glucose).*
- *The brain consists of around 100 billion neurons with 100 trillion connections between each other.*
- *Up to 1,200 litres of blood flow through the brain each day delivering up to 70 litres of oxygen.*
- *The left hemisphere deals with facts and details. The specifics of language, vocabulary and grammar also sit here.*
- *The right hemisphere has broader connections to emotions, empathy but importantly to the holistic and big picture view of the world.*

Some myths about the brain

The brain is fixed in size and does not change over life—many changes happen and due to neuroplasticity the brain is ever changing.

Alcohol kills brain cells—alcohol disrupts the firing patterns of the brain's neurons but does not kill brain cells (only in extreme over-indulgence).

Intelligence is genetic—intelligence is partly genetic but is more linked to ability to connect and draw on various resources in the brain.

Reason and rationality are separate to emotionality—the emotional centres of the brain operate together with emotionality taking a driving seat.

Behaviours are hard-wired—we have many instinctive reactions that are hard-wired but many behaviours are linked to our interaction with the environment.

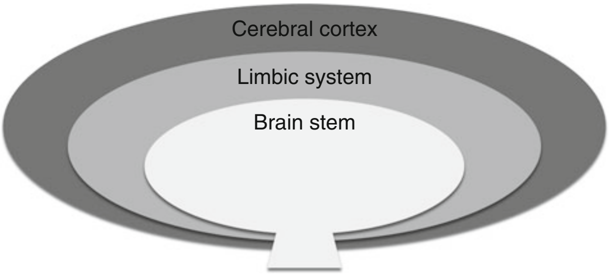

Fig. 2.2 Three-layer model of the brain

The brain is a complex organ with 100 billion neurons, brain cells that is, connected together in different formations and regions. In fact this seems so complex that it seems an illusion to believe we can understand the details and their subsequent influences on the rest of the brain and organism as a whole. Indeed it has been calculated that the number of possible connections in the brain is greater than the number of atoms in the universe. This may indeed be just popular science but it demonstrates, more than anything else, the sheer complexity of the brain. Yet when we look at the brain we can clearly see different structures and forms and we start to see that there is structure in the complexity. Like a country with millions of people who live in different households and in different villages and towns which are connected in different ways with paths, roads and highways. So it is with our brain. We can also see a general grouping of structures that simplifies the view of the brain even further. Though technically speaking neurobiologists speak of five regions, the three-layer model from the American brain researcher MacLean (see Fig. 2.2) is one that is simple and is generally speaking closely linked to reality (MacLean 1990). Though, we note, in the literature there is some discrepancy as to what structures actually belong to each, we can think of the brain in terms of

- The brain stem
- The limbic system
- The cerebral cortex

We will briefly look at these three areas and we will then draw attention to a number of structures that are particularly relevant to us in the context of neuroleadership.

2.3.1 Brain Stem

The brain stem is at the top of the spinal cord (including the upper part of the spinal cord) and the so-called small brain and back brain (cerebellum). This is the oldest part of the brain in an evolutionary sense. It is sometimes called the reptilian brain or the old brain. This part of the brain controls the incoming signals from the spine as well as basic reflexes and homeostasis—living that is: heartbeat, breathing, etc.

An important part of the brain stem is the thalamus (this is sometimes categorised in the limbic system). This is like a relay station for the sensory inputs.

All sensory inputs will pass though the thalamus and the thalamus does the first basic sorting and sending of signals to other parts of the brain. The thalamus is connected directly to the outer cortex, to the amygdale (emotional processing units) and to the hippocampus (for memory consolidation). In short the thalamus decides what information needs to be processed and at what level: unconscious or conscious. In some sense then the thalamus is a key centre for your consciousness, or at least awareness of the environment around us (the subject of consciousness is much debated by neuroscientists and philosophers alike).

2.3.2 The Limbic System

The limbic system is the next layer of the onion so to speak. It lies directly over the brain stem, deep inside the brain. It is, from an evolutionary perspective, the next oldest part of the brain and is sometimes called the inner cortex, the old mammalian brain or the middle brain. The limbic system has to some extent been popularised by much recent publicity in many popular books on person, and personality. Indeed it is of central importance because the limbic system is the emotional centre in our brain and processes a wide range of emotions (Bruce & Braford 2009; Ploog 1980; LeDoux 1991; Isaacson et al. 2001).

The limbic system is also tightly connected to the brain stem and particularly to the **hypothalamus** which plays a key role in linking the nervous system to the endocrine system—the hormonal system—via the pituitary gland. The hypothalamus controls various primitive impulses such as hunger and thirst but also body temperature, fatigue and sleep. It therefore has a role of putting our emotions into feelings (Brooks 1988).

The important structures in the limbic system are:

The **amygdala** (plural is amygdalae but it is in general used in the singular) are two small almond-shaped structures sitting deep in the brain and are considered our emotional processing units (the name stems from the Greek word for almond). Though they can be separated into different areas responsible for different functions their relevance to fear processing has been particularly intensively researched. The amygdalae are widely connected to other brain regions hence the importance of their functioning on the brain. They are considered key units for consolidating body memory because of their importance in processing pain and physical reactions to certain stimuli. This also makes them powerful in the retrieval and formation of somatic markers, emotional triggers that immediately stimulate a series of reactions (Bechara et al. 2003). This also makes them powerful triggers for learning processes (Kilcross 2000). They are however best known for their role in fear processing and their subsequent impact on the brain and body (see Sect. 2.7.2.1) (Davis 1997).

The **hippocampus** is considered the memory centre of the brain. This pair of "seahorse-shaped" (named after the Latin for seahorse) structures sit close to the amygdala. Research into London taxi drivers, for example, who are famed for their extensive and comprehensive memory of street names and the notoriously difficult test to become a Black Cab driver, has shown an increase in the size of the hippocampus (Maguire et al. 2000, Maguire et al. 2006). Some areas of memory such as spatial memory sit in the hippocampus itself. In other contexts the hippocampus seems to have a powerful memory consolidation function (Hynie and Klenerová 1991). Many memories exist as broad networks in the brain (engrams) consolidating, for example, auditory and sensory information also (Schacter 1996). However in absence of the hippocampus we cannot form new memories.

The famous case, in neuroscience circles, is that of HM who in 1959 due to uncontrollable epileptic seizures had parts of his brain removed including the majority of his hippocampus (Squire 2009). He subsequently awoke each day as if yesterday had never happened (the Hollywood film Memento, 2001, portrays a similar case). HM had lost the ability to form new memories and only had memories up to his operation. Since then each day was like the day after his operation. If he met you today and met you again tomorrow, it would be like meeting you again for the first time. (Oliver Sacks in "The Man who Mistook his Wife for a Hat" describes some similar cases but slightly different in nature and in region of the brain damaged (Sacks 1985)).

The **cingulate cortex** lies over the top of the limbic system like an arch and is actually part of the cerebrum, the innermost fold sitting directly on top of the limbic system. It is however considered a part of the limbic system as it closely matches and balances the information in the limbic system. Its functions are closely linked to attention, error detection and monitoring of the environment linking in closely with inputs from the hippocampus and long-term memory. Indeed some enthusiastic researchers claimed in 2008 (ironically meant) that "The cingulate cortex does everything" (Gage et al. 2008).

The **nucleus accumbens** we can consider the brain's reward centre (Wise 2002). Though it is now considered a collection of structures with slightly different functions it broadly processes most forms of reward and is responsible for production of dopamine (from the ventral tegmental area (Saunders and Richard 2011)), our reward hormone in the brain. It will also drive the excretion of oxytocin which is important for trust building and bonding (Liu 2003; Baumgartner et al. 2008). Habit learning patterns and procedural learning patterns are also consolidated here (Setlow 1997). This thus shows the importance of reward in consolidating new habits (see Sect. 2.5.2).

2.3.3 Cerebral Cortex

The cerebral cortex is, from an evolutionary sense, the youngest part of the brain and what is also considered its crowning glory. It is this first and foremost that differentiates us most from other animals and other advanced life forms. We humans have a huge cerebral cortex unmatched in its size and complexity. This is the outermost layer of the brain with deep folds and valleys. It is only a few millimetres thick and in preserved dissected brains is grey in colour, hence the term grey matter. This is also clearly visibly against the white matter, the thick layer that lies beneath this. The white matter is the myleniated axons ("insulted" connections between cells) connecting the cerebral cortex to numerous other areas. This layer is separated into four broad regions "cortices". Each of these perform a cluster of processes that are similar:

- **Occipital cortex**: sitting at the back of the brain and here most of our visual processing sits.
- **Temporal lobes**: sitting at the sides of the brain and where we process abstraction, metaphor and language.
- **Parietal cortex**: sitting over the top of the brain and here we process sensory inputs and coordination in space and time.
- The prefrontal lobes or **prefrontal cortex** (PFC) which is considered the seat of higher functions or executive function. This region is a strong focus in neuroleadership as here sit many of the controlled and conscious processes such as emotional regulation.

In addition to these the motor cortex, which sits like a band over the middle of the brain, is often treated separately to the above-mentioned lobes. The term lobe and cortex is often used interchangeably.

In each of these regions there are various sulci and gyri. Folds and ridges, valley and hills if you wish (sulci are the "valleys" and gyri are the "hills"). These have distinct regions that also have distinct functions which are very similar from person to person. These may be, for example, regions that process sound, visual processing of faces is, for example, closely correlated to one specific region (fusiform face area—FFA (Ganel et al. 2005)). We have centres for language comprehension, Wernicke's area, and for language production, Broca's area. The list is long and these regions are part of the specific focus of many neuroscientists and particularly in cognitive psychology.

Though it is easy to see the three layers of the brain from brain stem, to limbic system to the cerebral cortex as separate functional areas processing living functions, emotional processing and higher functions, these meta regions are all linked together and process information in parallel and with the help of each other. Survival instincts will influence our emotional processing and this will in turn influence our decision-making ability in the cerebral cortex. Or vice versa visual stimuli will be emotionally processed and then lead to an instinctive survival reaction firing strongly from the brain stem. The brain is a powerful interconnected unit and these systems function together to give rise to the multitude of reactions and processes that are part of human beings and what we are and how we function. Indeed until recently we considered the cerebral cortex to be the most important area of the brain where our rationality sits and where the seat of the higher man also sits. Recent work has shown that we are highly emotional beings and that the lower systems can and do control the direction of our thinking rather than the other way around. We are emotional creatures not rational creatures.[2] The brain's power indeed lies in the power of the connections. If we were to tie back the structure of

[2] "Descartes' Error" by Antonio Damasio is the now classic book showing that the rationality of Descartes was flawed and that emotions have much more relevance than we could possibly have assumed.

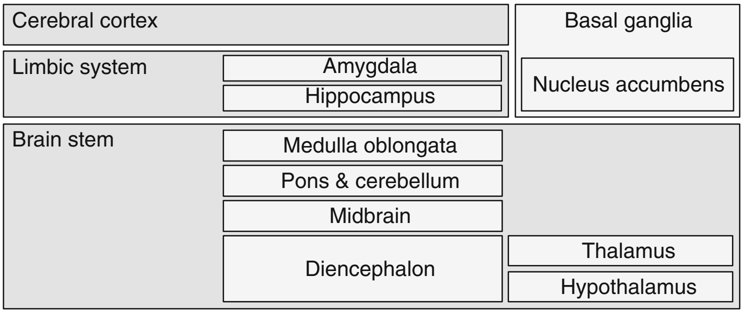

Fig. 2.3 Brain regions

the brain to Camerer's quadrants we would see that only the controlled cognitive processes (I) would be mostly processed in the cerebral cortex (see Fig. 2.1).

Figure 2.3 shows the specific regions in the three-layer model.

2.4 Information Processing in the Brain

The processing scheme of the brain shows how external stimuli are processed and give rise to an action and reaction. The stimuli are first processed in the thalamus and this functions as the first control centre. These signals are then sent further to the amygdala and to specific regions in the cerebral cortex. These stimuli are then balanced and compared to previous experiences and reactions.

These two systems the amygdala (and limbic system) and the cerebral cortex process the information differently and more importantly at different speeds. The amygdala which functions as a central emotional processing unit uses a high-speed reaction circuit which activates immediate emergency reactions. It is the amygdala that stimulates the release of adrenalin after only 12 milliseconds and can therefore immediately increase blood pressure and heart rate and ensure that the reaction ability of the body is intact (McIntyre et al. 2003; Davis and Whalen 2001). The cerebral cortex needs more time to form a reaction (a few hundred milliseconds, if not seconds) but it is also more precise as this will scan memories and stimuli for more precise information and make a more conscious decision based on the information coming in. You can think of it like this: you walk through a forest and see a coiled up shape on the ground. As you mind says "snake" you will likely jump back, your body will be energised and you will be ready to flee: your senses will have immediately focused and you will have heightened attention. This is the quick processing path, the emotional/amygdala path. Yet as you look closer you see that this coil is only a rope someone has left lying there and your more detailed processing sees this and our body will relax as we comprehend that it is only a rope and nothing to be worried about. This is your cerebral cortex focusing on more detail and coming to a more detailed analysis of the situation. You will likely laugh–which is a primal reaction to stress and this in turn will release calming hormones.

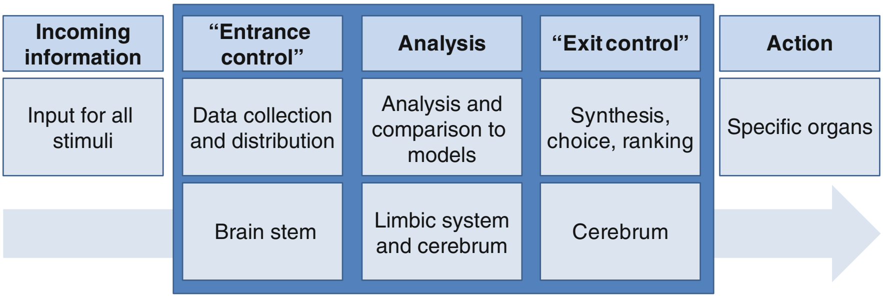

Fig. 2.4 Processing scheme in the brain (based on Seidel 2004, p 41)

Both of these centres work together and collaborate to come to better decisions as in the above example of the rope. They compliment each other—the primal amygdala reaction path protecting us and the cerebral cortex contributing to our higher functions and more detailed processing. Ultimately the cerebrum (specifically the preforntal cortex) can act as the director and can exert control over our actions and reactions (see Fig. 2.4) (Miller and Cohen 2001; Banks et al. 2007; Ochsner and Gross 2005).

2.5 Important Insights

In recent years there have been many breakthroughs in neuroscience and the research and number of reports have exploded—this can leave many who take an interest in neuroscience with a feeling of confusion and an inability to know where to start. For leaders and laymen it is even worse. We would therefore like to, from this plethora of information, draw your attention to a few insights that we find particularly important and relevant in the context of neuroleadership.

- The first important realisation is that of the brain's plasticity. This means the ability of the brain to reform itself and rewire itself. The brain is not as previously believed a fixed structure but rather an ever-changing organism. Specifically the connections between the neurons are forever changing—growing and shrinking according to how much we use the pathways. This means that we can "teach an old dog new tricks" that what is in the brain is not permanent and new learning can always take place (Kolb and Whishaw 1998; Shaw and McEachern 2001).
- The second important realisation is that emotions play a crucial role in these change processes (Rolls 2001). By activating the reward centre in the brain we can stimulate various processes that will contribute to enhanced learning, habit formation and positive emotions in the brain (Nakatani et al. 2009).
- Thirdly the discovery at the start of the 1990s of mirror neurons (see Sect. 2.5.3), that network of neurons across our brain mirroring others actions and that show that we are interconnected at a level never before thought feasible and that these mirror neurons are instrumental in many learning process but also in the reading

of emotions and empathy (Rizzolatti 2008). Emotions are truly infectious. These mirror neurons are considered so important by some researchers that they have been named (namely by the illustrious neuroscientist Ramachandran) the "neurons that shaped civilisation" (Ramachandran 2009).

We will now look into the biological basis of the brain to understand some of the underlying process better and see where they therefore tie into leadership contexts. Learning how neurons function and communicate with each can be particularly relevant for understanding how important learning, emotions and positive working environments are in a corporate context.

2.5.1 Plasticity

Plasticity is the ability of the brain to grow, regrow and reform its connections and functions. Plasticity is the heart of learning and of memory and one of the most important aspects of the brain we would like you to take away. The concept of plasticity is what drives the developing brain and all our learning processes.[3]

In looking into plasticity we need to look at the neuron, the brain cell. The brain has (a staggering) 100 billion neurons[4] and these consist of three main elements: dendrites, cell body and axon (see Fig. 2.5). The cell body is the metabolic centre of the cell. It is where the DNA lies and where all necessary substances for the functioning of the cell are produced. The cell has two types of connections that stretch out like arms or branches on a tree, indeed a neuron can look surprisingly like a tree or indeed a plant with its complex system of roots. The dendrites collect information from other cells. Each cell has numerous dendrites (in some cases up to 50,000 but on average somewhere around 1,000). There is then a single axon which connects to other cells, or specifically their dendrites. The connection between these is not a direct connection but a so-called synapse. The synapses are the connection points of cells yet these do not connect directly—there is a gap called the synaptic cleft. Information is transferred between two different cells through the release of so called neurotransmitters. These are chemicals that are released from the end of the axon, stimulated by the electrical current in the cell. These neurotransmitters then jump over the gap to dock into receptor cells that in turn stimulate another chemical process in the dendrite and send an electrical signal further to the cell body and potentially along the axon and so on and so forth (Kandel 2006). Your thoughts are thousands and millions of these minute chemical processes and electrical impulses (action potentials) travelling at speeds of up to 100 metres per second in the brain.

We now know that the connection process of neurons is very plastic and an ongoing process. The development of the brain in the embryo shows the magic of this process. The brain cells are initially produced in their millions and billions along

[3] The free publication "Brain Facts" from the Society for Neuroscience is easy to read, understandable and informative giving the basics of the brain, its development and disorders.

[4] Suzana Herculano-Houzel of the University of Rio de Janeira has put the actual figure at, on average, 86 billion neurons for a male brain.

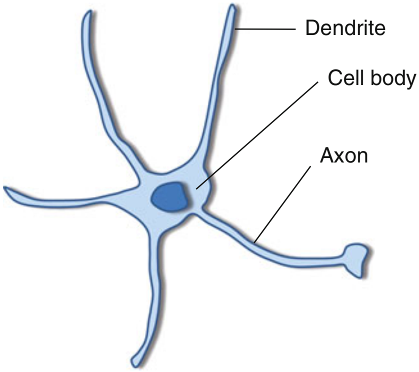

Fig. 2.5 A neuron

the neuronal tube in the primitive brain. These neurons then go through a great migration. They will then "crawl" along glial cells, cells that give structure and provide nutrition and support structures to neurons. The neurons then come to their final locations and once they reach their final location they will try to reach out their arms, dendrites and axons to connect together. We do not know how this neuron migration is coordinated at this time. This is a somewhat magical process whereby millions and billions of neurons migrate to predefined points in the early brain and then start connecting and forming into various regions and structures to give rise to a brain that is surprisingly similar in all humans (indeed in many animals the similarities are astounding) (Carey 2006). Brain cells are programmed to connect to each other. Figure 2.6 illustrates this process.

Another interesting aspect of the neuron formation is that after the cells have found their final place and start communicating to each other there are also various phases of cell death, or cell pruning (the first six months of human life are actually characterised by cell pruning, cell death, and not cell growth as we may falsely have assumed) (Kantor and Kolodkin 2003). Here cells or connections that are not considered important anymore are pared back. This phenomenon has been implicated in our, for example, limited ability in Europe to identify Chinese faces. To us Europeans all Chinese look very similar. And interestingly to Chinese all Europeans look similar. Yet infants have high sensitivity to faces and can identify a much wider variety of differences in similar faces than adults can. Infants of three months are much better at identifying Barbarey Macaques—small monkeys which look extremely similar (their keepers cannot distinguish them). This ability is lost after nine months (Pascalis et al. 2005). The theory is simply that after we find that we do not need our Chinese face neurons these will be culled and we lose the ability to identify Chinese faces and so they all seem similar. The same goes for the Chinese who lose their European face neurons and have trouble identifying European faces even though for Europeans this may seem obscure as we consider ourselves so

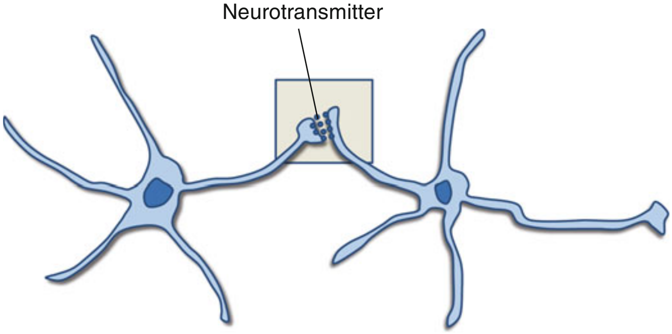

Fig. 2.6 Neurons connecting through a synapse and neurotransmitter

different—but only if we have the neurons that can do this processing. Familiarity over time plays a major role also, obviously, meaning that if we live in China, for example, for a period of time our sensitivity to Chinese faces will increase.

Neuronal learning also highlights this process and in some ways the heart of our learning processing lies at a micro neuronal level. The work of Eric Kandel, Nobel laureate in 2001, showed something powerful.[5] Short-term memory is a chemical process i.e. extended firing of neurons over seconds and minutes that allows us to recall the memory. Long-term memory is a physical process—the stimulation of the brain cells will produce amino acids that will stimulate the growth of new dendrites and will build physical connections—memory is indeed a physical structure. A long-term memory is a physical connection in the brain (Kandel 2006). So any new memory you form means you have changed your brain. This highlights the true power of plasticity for if we are forming new memories, we are rewiring the brain and this above all answers the voices of those sceptics who believe you "cannot teach an old dog new tricks". We can all rewire our brains: any new memory, be it of football match, a new computer programme, a new emotional event, whatever, is a new physical connection in the brain. This is powerful for our purposes in the broader context of neuroleadership.

Another interesting point we need to note when speaking of neuroplasticity is that of neuronal learning. That is, as an organic cell and not a hard electrical circuit, the cell itself learns to distinguish between signals and change it's firing. When a neuron is stimulated with an electrical current there will also be an electrical output. This, however, will not remain stable. If the electrical current is repeated over time repetitively the electrical output will decrease. The cell has learned that this is repetitive and so it creates a *lower* stimulation. This is known as *habituation*. If a few smaller electrical signals are given and then large "shock" signal given, then the following stimuli, the same as the initial small inputs, will give an *increased*

[5] Eric Kandel's book "In Search of Memory" is a fascinating read documenting his life and the devleopment of neuroscience and his work after the Second World War.

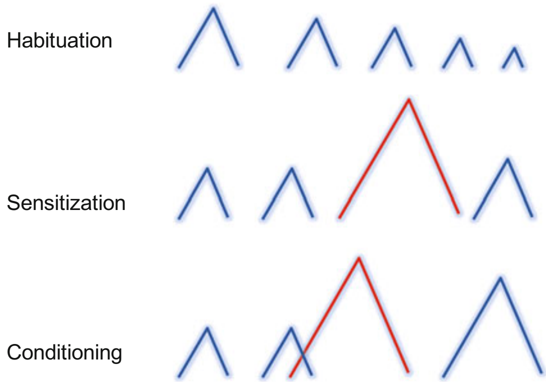

Fig. 2.7 The three forms of neuronal learning

output. This is known as *sensitisation*. Then we come to the classic conditioning processes whereby a large shock signal is given closely following a small signal. This small signal will then stimulate a *large* output (Kandel 2006).

This understanding of neuronal learning is important as it shows that our cells are forever becoming habituated, sensitised and conditioned and that many concepts that we may class as "psychological" may in fact be grounded in the biological learning of the cells sitting in our skulls (Kandel and Tauc 1965) (Fig. 2.7).

The process of developing connections between neurons in the brain can be seen diagrammatically in Fig. 2.8. The first phase shows how neurons reach out to connect to each other. The initial connection happens in the second phase and these cells then start communicating to each other based on the stimuli coming in leading to stronger pathways in the third phase. If these pathways are continually used and stimulated this will lead to strong pathways in the fourth phase.

This knowledge of neurons, their connection processes, their learning processes and the brain's plasticity is extremely important for us. It is extremely important because this demonstrates that it is our experiences that build our brain. The stimuli that are coming in and have come into our brains all through our lives have stimulated various learning and connection processes in the brain and this influences the way the brain wires together. Our environment and our experiences *do* develop our brain (Hüther 2006). It also demonstrates, as we keep mentioning, that learning something new is always possible. This difficulty lies in the fact that we may be fighting solid *physical* connections in the brain.

2.5.2 Reward System

The reward system is a complex connection of regions that has now been extensively researched in humans and in animals. The reward system is simply the system that generates those good feelings. This we now know is generated through the dopamine system which we can see as the brain's "happy hormone"—it

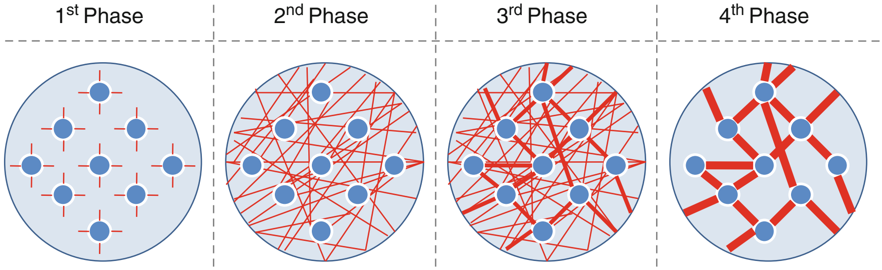

Fig. 2.8 Neuronal connection patterns (Based on Hüther 2006)

stimulates the feeling of happiness and elation (it is, however, we note, involved in many processes) (Arias-Carrión et al. 2010). It is, incidentally, exactly this system that cocaine stimulates.

The earliest research into this system was done on rats (Olds and Milner 1954). Electrodes were implanted in various areas in the brain and the rats could self-stimulate this. It was discovered that in certain areas a feeling of happiness was generated. In some cases this was so intense that these rats would continually keep stimulating the electrodes and neglect to drink or eat.

The dopamine system is now a well-researched system in the brain. Dopamine however is not just reward it has many important functions as a neurotransmitter. It is dopamine that is also essential for attention—our attention system is driven by dopamine but more than that: motivation at a chemical level can be seen as a dopamine process (Nieoullon 2002).

The reward system functions in many ways in humans but researches have split these into two systems of reward: primary and secondary rewards. Primary rewards are those simple survival needs which also generate powerful feelings of reward and happiness and satisfaction. Primary rewards are: food, drink, sex, shelter. This explains our feelings of satisfaction after a good meal and our consistent (and obvious) desire and attention to food and drink. Secondary rewards are rewards that are not directly linked to our primary rewards or only at a secondary level and many arguably help our survival e.g. status shows a primitive level of hierarchy and hence ability to survive and find a suitable mate. Secondary rewards may include:

– Information
– Status
– Acknowledgement
– Gratitude
– Social value
– Altruism
– Trust
– Physical contact

These illustrate more than anything that human beings are driven by many factors and the assumption in many corporations that reward is driven only by money is a fallacy and a dangerous one. Reward and pleasure have a multitude of complex connections and associations (Kringelbach and Berridge 2009). We should note that human beings are intensely social and this is represented also in our reaction to reward, particularly the rewarding experience of social interactions (Adolphs 2003). This may also remind us of the concepts of man we spoke about in the previous chapter—the original homo economicus assuming our only system of reward is financial. The homo sociologicus showed that we were driven by other factors. Indeed this is the strength of the brain-driven model of man because we are now more able than ever to give clearer explanations of the internal motives of man. They are after all represented in the brain. More importantly, reward, attention and motivation are all elements of the dopamine and reward system. Hence many corporations view of motives needs to be reviewed.

The reward system is, however, more than simply reward and motivation, if that is not enough in itself. It is also essential for learning processes particularly habit learning. Positive reinforcement is a key element of learning and this is an element of the reward system. The opposite, fear conditioning, is a form of learning but the impacts are negative and put the body into a state of stress (Nakatani et al. 2009). Tapping into reward is an essential part of this process and one that will drive motivation and collaboration powerfully in any organisation.

Understanding these systems in the brain is important as the neuroleader is a leader that has the ability to understand the brain and understand the deeper drives and therefore is better able to tap into this potential and hence the potential of the workforce and each individual. Understanding individual reward systems will enable the neuroleader to better tap into the powerful drives of motivation and satisfaction of individual employees.

2.5.3 Mirror Neurons

The history of mirror neurons goes back to a neuroscience lab in Parma, Italy of the now illustrious neuroscientist Giacomo Rizzolatti (Rizzolatti 2008). During experiments with monkeys into the function of the motor cortex something unusual happened in a lab situation: a particular monkey had a motor neuron of arm movement wired up to a computer for this particular research. A researcher in the laboratory ate a snack in front of this monkey and as the researcher raised his arm the motor neuron of the monkey activated even though the monkey's arm had not moved. This should not have happened. This, the researcher at first thought, was a faulty reading or that the technical equipment was malfunctioning. It was not. Repeating this action the monkey's motor neuron activated again and again while simply watching the researcher. These neurons were subsequently named mirror neurons. Neurons that activate while watching somebody else move—mirroring their actions in our own brains (Rizzolatti et al. 1996).

The paper Rizzolatti wrote was initially rejected by the journal it was submitted to for its lack of general interest. However, it was shortly after almost euphorically received and this has led to an impetus of research into mirror neurons in primates and humans. Indeed they are considered essential elements of our social brain, our ability to connect to others and are implied in fields such as learning by imitation,

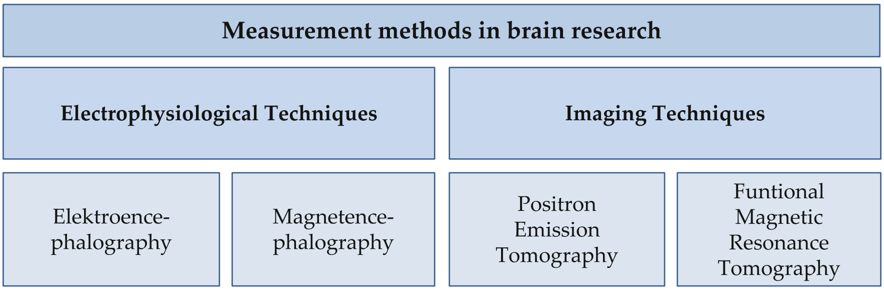

Fig. 2.9 Methods of brain research

empathy and even the building of civilisation (Ramachandran 2000). Many highly respected neuroscientists have drawn our attention to their value. Autism has, for example, been implicated in dysfunction of the mirror neuron system (Williams et al. 2001).

Mirror neurons can activate to actions, emotions but also intentions. This shows that we are connected to the world around us and we live a little bit of the actions but also the emotions and intentions we perceive (Rizzolatti and Fabbri-Destro 2010). This is the value of the social brain: we *are* connected to the environment and the people around us.

The strength of the mirroring is however, affected by various factors:

- The emotional development in childhood affects significantly ability to be able to connect and empathise (Gordon 2003).
- Mirroring is stronger when it is directly linked with satisfying a particular need.
- Mirroring works best when the observer can understand and is familiar with the context of the observations.

Different areas of mirror neurons have now been mapped and these cover large regions of the cerebral cortex and especially the motor regions. In a simplified understanding these are the neurons that help us connect to each other including inter-brain synchronization during social interaction (Dumas et al. 2010).

2.6 Methods of Brain Research

The current methods of research are responsible for the amount of knowledge we have about the brain: it is also the development in the technology that we have to thank for the information that we have. It is after all the advances in these areas that have driven the depth and clarity of knowledge. Though there are a wide variety of techniques now available we will look at the most common which account for the vast majority of research. We can put the techniques into two categories (see Fig. 2.9). Firstly techniques that measure electrical activity in the brain: electroencephalography (EEG) and magnetoencephalography (MEG). These measure the minute electrical impulses in various regions and operate in real time. These show us the immediate electrical reactions in the brain in certain regions in the cerebral cortex. Secondly the ways of imaging the brain, techniques that can give pictures of

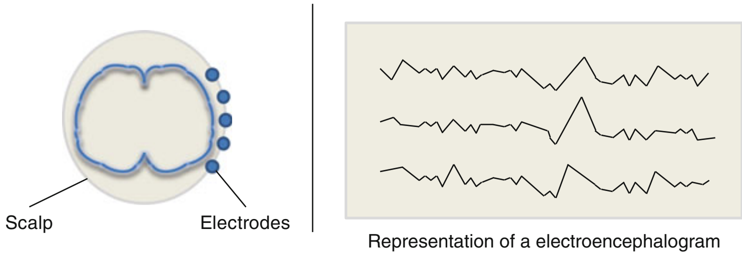

Fig. 2.10 Electroencephalography

the brain and its workings. These techniques measure the increase of activity in various regions of the brain. The measurement is based on various criteria such as increased oxygen use in these areas or transfer of water molecules. These give the very popular coloured 3-D diagrams showing the precise regions activated, importantly also deep in the brain (Matthews and Jezzard 2004).

2.6.1 Electroencephalography

Electroencephalography (Davidson et al. 2000) is one of the oldest techniques in neuroscience research. You will be familiar with the pictures of people sitting with electrodes over various parts of the head. It origins go back to the 1920s. In today's scientific environment it is now seldom used independently but still has the advantage that the readings are real time in microsecond intervals which is an advantage over the imaging techniques which are only taken in intervals of a few seconds. As we know the brain communicates at microsecond intervals and so this can show immediate reactions to a stimuli. In addition it is a cheap technique, it is transportable and can be used in a variety of contexts. More than that it enables the researched person to be able to move to a limited extent or sit at a computer for example which is not possible, or difficult, with other techniques. Currently there are now various simplified EEG models on the market used for techniques such as neurofeedback and in some cases simple popular brain programmes.

The electrodes are fastened to the head (or a cap is used) and these pick up the fluctuations in the electrical patterns. As we know neurons communicate with small electrical impulses (known as action potentials) that are generated by differences in the so-called ion channels. These minute electrical impulses can, when regions of neurons activate, generate an electrical current that can be measured on the scalp (Fig. 2.10).

2.6.2 Magnetoencephalography

Magnetoencephalography (Ioannides 2009) is a development of EEG and was developed at the start of the 1990s. This technique measures the magnetic fields

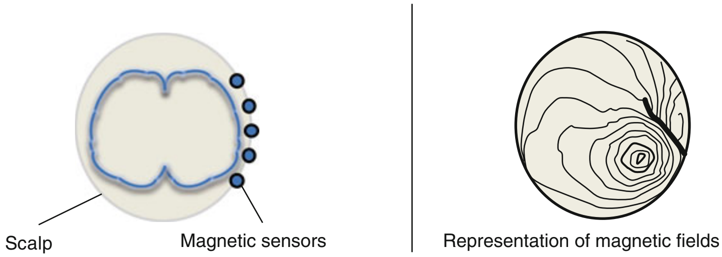

Fig. 2.11 Magnetoencephalography

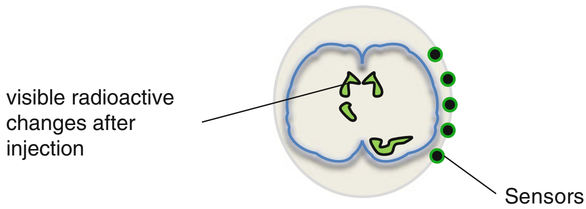

Fig. 2.12 Positron emission tomography

produced by the brain. This give a magnetic field picture of the brain and it fluctuations and changes but its advantage over EEG is that it can also show activity in the deeper brain regions and not just in the outer layers of the cerebral cortex (Fig. 2.11).

2.6.3 Positron Emission Tomography (PET)

Positron Emission Tomography (developed around 1974) measures the radioactivity in glucose after the candidate has been injected with a radioactive glucose liquid (see Fig. 2.12) (Casse et al. 2004).

This weakly radioactive substance can be taken up by the brain and it shows the regions that are using higher levels of glucose (the brain's energy source) and hence pointing to the regions that are most active. This activity can then be mapped onto 3-D model of the brain and we can therefore see models of the regions that are activating and not activated to given stimuli. The images given here, though using different techniques, are similar to those produced by Magnetic Resonance Imaging (MRI).

2.6.4 Functional Magnetic Resonance Imaging (fMRI)

Functional Magnetic Resonance Imaging (Matthews and Jezzard 2004) is very common in research because of the widespread availability of the machines, despite

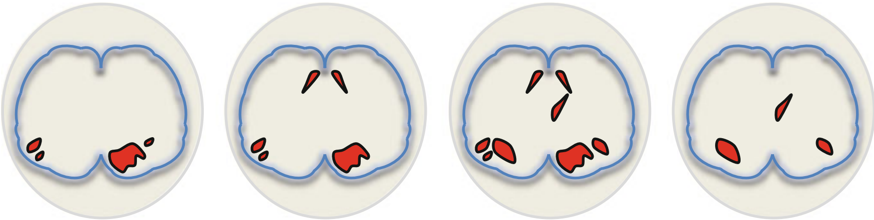

Fig. 2.13 fMRI images

their cost. The machines are so widespread because of the value of their abilities. Magnetic Resonance Imaging measures the movement and magnetization of molecules in the body. These can give clear 3-D pictures of the whole body in detailed clarity and minute detail of internal organs. Magnetic resonance imaging as a technique, in spite of it's value in detecting brain tumours, for example, is of little value in functional and cognitive fields because a picture takes minutes and only represents the structure and not the function. The functional technique therefore uses information gleaned from the haemoglobin molecules (relating to blood supply) and can in much quicker snapshots measure the change in oxygen usage in different parts of the brain. These snaps are in time frames of around 3 s. These are then plotted onto 3-D maps of the brain showing close to real time activation of various areas of the brain—as neurons activate so do their oxygen consumption. The pictures represent the areas of oxygen usage in different parts of the brain and the subsequent images are in 2-D or 3-D (see Fig. 2.13). The images it should be noted do not directly measure the neuronal activity but that of oxygen usage.

2.6.5 Diffusion Tensor Imaging (DTI)

Diffusion Tensor Imaging (Tournier et al. 2011) is an MRI technique. This has only recently been refined to a level that it is increasingly being used in neuroscientific research. It has its roots in the work of Michael Moseley in the early 1990s who reported on the water molecule movement in white matter (the myleniated axons connecting the cerebral cortex to other areas in the brain). This has since 1995 been increasingly used in research. Its real value lies in being able to detect the pathways and connections in the brain. From these multitude of regions in the brain not all are connected to each other and to be able to observe these connections, the paths and highways between regions, is increasing our understanding of how parts of the brain communicate to each other.

2.6.6 The State of Play on Technology

The above are the most commonly used techniques. There are, however, others: Computed Axial Tomography (CAT), Single Photon Emission Computed Tomography (SPECT) to name some common abbreviations in neuroscience. However these are falling into the background particularly those that require injection of radioactive fluid (as the above do) as this is an invasive technology and limits the amount of research that can be carried out on any one individual. So all forms of MRI are the preferred technique, this in itself is becoming ever more refined with techniques such as diffusion tensor imaging but also ever increasing ability to obtain readings at smaller intervals moving closer to real time measuring of the brain's activity.

EEG is used relatively seldom nowadays as an independent technique but is still often seen used in conjunction with other techniques to gain insights into real time activation. It has reached a new niche in neurofeedback which can be used successfully in some serious dysfunctions such as autism but also in popularised cases of sports psychology, in anger management but also in brain computer interface "games" claiming benefits of the brain. However here also further technical developments are showing better levels of reading at deeper levels in the brain.

Further research is also looking in to the gene activation in the brain. The Allen Institute for Brain Research (set up by Microsoft founder Paul Allen) has recently completed a full genetic mapping of the brain in mice (Lerch et al. 2009) and humans (Holmes 2011) including also a mapping of genetic expression during development (in the mouse brain) (The Allen Brain Atlas can be visited and searched online at: http://www.brain-map.org). These are exciting discoveries but with less immediate impact for neuroleadership: Genetic expression will show how different neurons express themselves and how they react to various neurotransmitters and hence is incredibly important for looking into various neurological disorders.

In research two other areas of knowledge are also tapped into. The first, and the oldest methodology apart from dissection of the brain is that of tumour research. When we know a patient has a tumour or lesion in a part of the brain, we can see what changes occur in this patient's behaviour. Much early work was based on this. The famous case of Broca's area (speech production) and Wernicke's area (language comprehension) were discovered based on tumours in patients and these descriptions of the changes in behaviour that occurs as a follow on from this—in these particular cases aphasia, the loss of parts of language.

In research Transcranial Magnetic Stimulation (TMS) (Kobayashi and Pascual-Leone 2003) is a technique commonly used. This technique activates various parts of the brain through light magnetic signals from electrodes placed on the scalp. This means that an area of the brain can be activated or inhibited. The electrical signals will disturb the electrical function of the neurons in that region and so scientists can "shut down" a region and then research the effects of this (or increase the stimulation depending on the frequency used).

As we write this in 2012 we are in an exciting time as the technology is ever improving and we are seeing better and better imaging techniques. Diffusion Tensor Imaging shows a powerful part of the picture, as the connections are essential to understanding the brain's functions. The increased speed of fMRI is also giving us a more realistic picture of the brain. Though we are a long, long way from being able to mind read, to read thoughts and intentions from the scans, these techniques are ever more being used in criminal cases. In September 2011 Professor Jack Gallant at UC Berkeley released a report documenting the reconstruction of images being viewed on video (Nishimoto et al. 2011). Though crude the computer reconstructions from the brain imaging were at times clearly identifiable.

The research into gene expression will likely be fundamental in finding deeper clues to neurological disorders. We expect the technology to continue advancing and to have ever more refined view of the brain in all fields of research.

We will now look deeper into the actual results of this research and into the brain and particularly that of emotions.

2.7 The Impact of Emotions on Neural Processes

When we speak of emotions scientists are all aware of their impact on the human being, indeed emotions are an integral part of being human and our consequent actions and reactions. Our language also reflects this importance with a huge amount of descriptive terms for emotion of all colours and forms. Yet, this said, there is no definitive taxonomy of emotions and no generally accepted method of classification. We will, therefore, look into what we mean by emotions and define the terms of affect, mood, feeling and emotion (Schönpflug 2000).

Affect is the experience of feeling or emotions and represents a response to stimuli. We use it here to refer to it as a response that will have some form of emotional or physical manifestation whether consciously processed or not. These can also be the less consciously processed emotions which will affect the mood of the employee in the workplace without having significant emotional impact. These affects are important parts of the workplace as many may be instinctive and short lived but contribute to the whole experience of an emotion and its physical manifestation but also of the behavioural manifestation. If an emotion is affective it will drive to action.

Moods are representations of broad emotions in a form that influences an individual over time and colours the way we see the world during that mood. Many people will speak of being in a good mood or a bad mood and we have many words to describe these. We can see moods as the spectacles though which we are currently seeing the world but these will also have significant impacts on motivation and interpersonal interactions in the workplace. An event which triggers a strong emotion can give rise to a mood. Yet many moods have no clear conscious trigger. In this sense also moods are the mix of emotions that we are experiencing that will then produce a broader emotion represented as a mood. Notably these can also have positive or negative knock on effects and this is particularly significant in the work place. Fiedler noted that people who are positive and optimistic are more trusting and place more trust in their environment, master problems better and develop creative solutions quicker (Fiedler 1988). People who are more negative look more for safety, are afraid to make mistakes and are often tense. Interestingly moods in the workplace are rarely measured. With the exception of the usual employee satisfaction surveys there seems to be no interest or way to measure the moods of the workforce and little effort is being made to approach this. Yet it is likely that precisely these moods are having subtle and powerful effects on the way the work is being carried out.

Feeling is a term which is often used interchangeably with emotions. The etymology shows us clearly what drives the meaning here. Feeling, from the stem feel, is the physical representation of an object e.g. of warmth. Thus feelings are classed as the conscious subjective experience of emotion. Feeling is the affect of emotion. This is the physical manifestation and representation of an emotion and not the emotion itself. "I feel warm inside" may represent the emotion of love but also of friendship of gratitude and many more. Feelings are the body's internal communication system of emotion and are also driven strongly by the hormones and chemicals in the brain (see Sect. 2.9.1).

Emotions are the psychophysiological state of mind from the interaction of internal and external processes. These are conscious manifestations that will colour our feelings and internal representation and affect our subsequent mood. There are a wide variety of emotions we can experience which we can see as scales on a rainbow with various emotions colouring others and these can be experienced with a variety of intensities. Think of the word happy: elated, joyous, satisfied, are all variations of this. Some people separate basic emotions and complex emotions. The basic emotions working somewhat like the primary colours and the complex emotions are variations and mixes of these. Paul Ekman the world's leading expert on facial expression categorised six basic emotions in the 1970s: anger disgust, fear, happiness, sadness, surprise (Ekman et al. 1982). He expanded this list in the 1990s to include: amusement, contempt, contentment, embarrassment, excitement, guilt, pride in achievement, relief, satisfaction, sensory pleasure, shame.

Emotions are particularly relevant for corporations because these will affect the mood. But more specifically if we are talking about the brain-directed man, we know that emotions come in combination with chemical processes in the brain and body and these will have an affective impact meaning increased energy increased, or decreased motivation, increased focus, etc. Furthermore we also know from the research into mirror neurons that emotions are also mirrored and hence to no small extent infectious. Emotions of individuals and of the mass will be directly impacting the mood in any business and on the general atmosphere and in turn the chemical balance in the brain and body and in turn ability to operate optimally in any given context.

2.7.1 Emotional Intelligence

In parallel to the increased understanding of emotions and their fundamental importance in the brain the concept of emotional intelligence has also developed. Emotional intelligence was first proposed, in some form, in 1983 as a result of Howard Gardener's work into multiple intelligences whereby he defined intrapersonal and interpersonal intelligence as one of eight "intelligences" (Gardner 1983). Emotional intelligence became a mainstream movement in the 1990s with Daniel Goleman taking a leading role in its conceptualization (Goleman et al. 2001). We now have a more refined understanding of what emotional intelligence constitutes. Daniel Goleman defines five competencies on the two axis of Intrapersonal and Interpersonal Competencies (Fig. 2.14).

Dimensions of emotional intelligence	
Intrapersonal competencies	Interpersonal competencies
Self-awareness	Social awareness
Self-regulation	Social competence
Self-motivation	

Fig. 2.14 Dimensions of emotional intelligence

Self-awareness is the ability to be able to introspect and to be aware of one's own feelings and motives and also one's own effect on others. It includes being able to identify one's own moods, feelings and motivations, to understand how we respond to various external, or internal, stimuli. But also to understand one's effect on other people, how other people react to ourselves, our actions and comments.

To be able to control one's own mood and be minimally affected by external stimuli. To have an own mood which is not affected by external input. A person with high self control will not jump to impulsive decisions but will think clearly and make well-thought out and controlled decisions.

According to Goleman if you have **self-motivation** you will, and can work on problems and projects without an external extrinsic reward such as money or status. These people can follow, with energy, zeal and commitment, a goal to its completion for the sake of its completion and nothing more. Commitment and optimism will help overcome any hurdles and setbacks.

Under **social awareness** empathy plays a leading role: the ability to put oneself in another's position and share their emotions and standpoint without getting pulled under by these emotions or perceptions. In this sense empathy increases our ability to understand other people and also understand their motives and drives to a deeper and more fundamental level. Generally this also goes hand in hand with a clear understanding of one's own emotions. Furthermore social awareness includes the whole set of competencies that is needed to read emotions and the impact of these on others in social contexts.

Social competence is the ability to adapt to social situations and configurations and in these varying contexts to be able to inspire and influence through effective communication skills and in addition the ability to relate and tap into other's emotions and motives. It is also about collaboration and ability to build relationships and build bonds with others and includes, amongst others, conflict management and the ability to leave people feeling valued.

We approach emotional leadership in the context of neuroleadership and the four basic human needs in Sect. 5.4.4.

2.7.2 Neuroscientific Aspects of Stress and Fear

We would now like to look into specifics of emotions to illustrate the importance of these to the body and illustrate the underlying processes. These, we feel are essential to understand in the context of neuroleadership. We will specifically

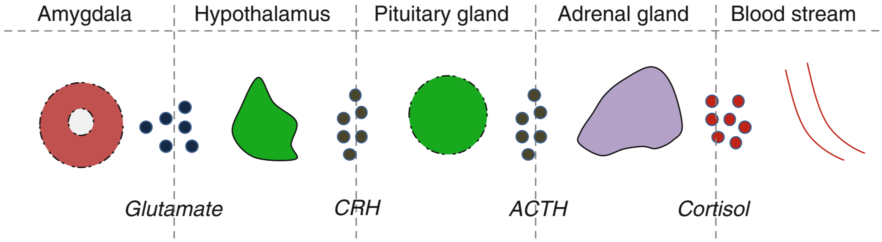

Fig. 2.15 HTPA-Axis

look into one of the most important stress responses: the HTPA-Axis (hypothalamic-pituitary-adrenal axis) (Swaab et al. 2005). This axis we use not to demonstrate the complexity of the chemical and hormonal processes but to understand the connections that the brain has with the body and the immediate short-term and long–term impact this can have on the human being in or out of corporations. The specific terminology is therefore less relevant for us but we would like you to understand the powerful connections and principles that drive this. Figure 2.15 is a diagrammatic representation of the HTPA-Axis.

Fear activates the amygdala in the brain which in turn will, through release of the transmitter glutamate, activate other regions in the brain stem and hypothalamus. This kicks off the stress-response cascade. The hypothalamus releases CRH (corticotropin-releasing hormone) which in turn signals to the pituitary gland to release adrenocorticotropic hormone which is sent into the bloodstream stream and then circulates to the adrenal gland where it binds and then stimulates the final step in the cascade, the release of cortisol into the bloodstream which has a widespread impact on the system.

Cortisol functions in many ways but helps the body fight the stress by releasing and redistributing energy to critical parts of the body e.g. the heart and away from non-critical parts of the body (in the short-term) e.g. the digestive system. Importantly it will also immediately take away resources from the body's immune system. These are in the short-term and for short-term stress reactions of little consequence to the body. It is after all a natural system of defence and a natural reaction and serves a purpose. However chronic stress over lengthy periods, as we can understand with the above description, will have a significant impact on the system and can be a cause of increased sickness and deterioration in health in addition to a whole host of others symptoms in various parts of the body.

Fear however, is processed differently by different people: from one's own perception of what fear is but also there has recently been a so-called anti-stress gene identified that controls and regulates CRH production and its over or under production (Amir-Zilberstein et al. 2012).

However the real danger of fear lies in its physical representation in hormones and chemicals in the body which imbalance the system. Furthermore these can then become associated to various stimuli and become conditioned into the brain and the body.

Leading by using fear, we can see in this short section, is for certain going to lead to a host of negative effects and impacts on human beings. The misconception that "fear can motivate" lies not in the fact that fear is a motivator but that fear can get to action, particularly in absence of any other ability to "motivate" (Nakatani et al. 2009). The host of negative impacts should lead us to use other more positive motivational drivers which will lead to healthier corporations. Obviously the reward system here is a better motivator and, indeed, dopamine is a powerful counter chemical to stress. Simply by showing interest in a person and being friendly and helpful has been shown to reduce fear and subsequent stress.

We will now look into the brain to see what distortions fear has on the brain's regional functioning. This will highlight the importance of fear and what a powerful force it is in distorting and manipulating the brain, drawing it into a negative spiral which will cause all sorts of disruptions in the brain and indeed even inhibit higher cognitive abilities.

2.7.2.1 Functional Impact of Fear in the Brain

Fear as outlined above has a significant negative impact on the hormonal balance in the brain and in the body. This can, in extreme cases, particularly with long-term fear, anxiety or stress, lead to conditions such as burnout. However looking into the regional activation in the brain paints a worrying picture of specific regional brain inhibition and activation which is also a cause of concern for businesses. Indeed even at a macro economic level this has a significant impact.

As we know the amygdala is directly connected to the prefrontal cortex, the frontal lobes of the brain, where many of our executive functions sit. This includes regions that balance emotions in the orbital frontal cortex in advance of making decisions. What research has also shown is that the prefrontal cortex can also exert control over the amygdala (Dolan 2007). This connection is a two-way street. This is encouraging as it means we can control our emotions to a degree. However, this connection is problematic in that we know that an overactive amygdala can inhibit functioning in the prefrontal cortex. This includes a region called the dorsolateral prefrontal cortex. This region specifically is also responsible for short-term memory (Petrides 2000). What this means is that, in short, an overactive amygdala will inhibit rational thinking and information balancing in the prefrontal cortex but also reduces our short-term memory leading to a decreased ability to deal with complexity. Short-term memory and fluid intelligence seem tightly linked together and our ability to keep things in our mind so that we can balance and compare them (Shelton et al. 2010). In summary fear decreases, cognitive ability—our ability to process complexity. Fear, in short, makes us stupid.

*A study by Feinstein et al. (*2010*) documented the case of SM a woman who has a rare condition called Urbach–Wiethe disease, which has destroyed here amygdalae. Her response to typical fearful situations was non-existent. Horror films amused her, she said she didn't like snakes but had not fear of them. She lives in a poverty stricken area and her life has been threatened on two occasions but she displayed no fear or urgency in theses situations (but did feel anger).*

A further impact of an active amygdala is that it will activate the fight or flight response system and this means an increase in energy. The fight or flight response, as the name implies, means that the body will put itself in a position to fight, with increased energy and aggressiveness, or flee with increased energy (more correctly it should be the "freeze, fight, flight or fright" response) (Bracha et al. 2004). Both will also lead to a focusing of, a narrowing of, vision onto the single point of danger. This excess energy can lead to increased action in combination with aggressive protective behaviour. This will counteract any collaborative activities. The urge to flee will manifest itself in the workplace with individuals ignoring, or not tackling, current problems and issues, running away from them so to speak. A further effect is the freeze response when the motor cortex is effectively shut down. The freeze reflex will manifest itself in an inability to act in business scenarios, including an inability to make decisions. These fear reactions are significant for corporations as this means either thoughtless action or inaction both of which have the ability to severely negatively impact any corporation.

In addition to this, research has shown that what we normally implicitly feel, is indeed supported by science, namely that our perceptions and bias changes. We shift our bias to negativity (Sharot et al. 2007). In a previous example we used the analogy of seeing a coiled rope lying on the ground and immediately mistaking it for a snake. Negative bias means that even though we realised it was not a snake, our sensitivity to snakes will have *increased*. If it were a snake we would assuming we escaped this one safely, which is statistically very probable, increase our focus and be increasingly sensitive to snake-like shapes in the surroundings. Specifically in the brain the anterior cingulate cortex (ACC) sitting above the limbic system, as we have noted, is a structure that, amongst others, helps focus our attention and monitor the environment for discrepancies. This area becomes active and will increase its negative bias now finding more and more snake-like shapes in the environment. The immediate effect of this in a businesses context is that in times of fear the negativity will increase and the chances of finding negative information also (Whalen et al. 2001). This can in turn influence the whole mood of an organisation. Furthermore this is also important and observable at a macroeconomic level. It will also explain how the popular press works as, for example, recession looms, fear will seep through society and our sensitivity and attraction to further negative events increases. The newspapers will slowly fill with negative stories and we will be drawn along in an ever-increasing flood of information which will in turn continue to activate our fear centres (Fig. 2.16).

The reaction to fear itself is an impulsive survival instinct and important to us—yet the danger this poses to us in the field of neuroleadership is that we are no longer scanning the environment while roaming through the undergrowth of the countryside, we are operating in corporations and need to deal with complexity and need our cognitive powers to work creatively and efficiently and moreover to operate collaboratively. Fear will counteract this ability and give rise to focused aggressive behaviour, with an inability to deal with complexity, reduced cognitive powers and a host of hormonal imbalances.

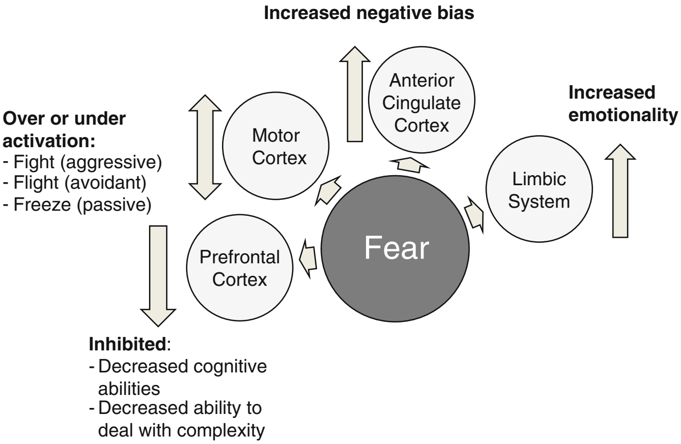

Fig. 2.16 Functional impact of fear in the brain

2.7.2.2 The Power of Faces and Unconscious Fear

In Sect. 2.5.3 we noted how mirror neurons link us to the actions of others. This is also reflected in the brain's reaction to faces. Specifically research into our reactions of fearful faces shave shown that just by looking at fearful faces this will stimulate our amygdala, stimulate fear that is (Whalen et al. 1998). This demonstrates how connected we are to our to the environment around us and particularly the people around us. This is also very relevant for corporate environments and the emotions that are demonstrated and expressed, openly or not, in corporations. Corporations are after all groups of people whose emotions will be influencing each other.

The more interesting research, though, is that of a similar set of experiments, as in the above studies. Specifically looking into our reaction to masked, subliminally presented that is, faces. In masking techniques a series of pictures will be shown and between these, other "masked" images will be inserted. These are masked by exposing these at an exposure time of less than 30 ms. Below 30 ms we do not consciously process visual stimuli but only unconsciously. If exposed below 10 ms no response conscious or unconscious can be seen. When fearful faces were masked, inserted that is, between normal images at exposures of less than 30 ms, the amygdala also activated even though the subjects had no conscious knowledge that they had seen fearful faces (Whalen et al. 1998). This shows that fear can be processed unconsciously *without* our explicit knowledge. This is also very relevant for corporations because in fearful environments we may not even be conscious that fear has activated and the functional differences we noted above may be distorting our thinking processes.

2.7.3 Functional Effects of Emotions in Organisations

Subjective and interpersonal emotions fulfil an important function in daily business (and yet are rarely mentioned in business literature). An emotional free business environment that many seem to have strived for, is not only unrealistic and a fallacy, it is nigh near an impossibility. Having emotions is what defines us as human beings and defines our sense of self. Emotions also have various clear functions in organisational contexts (Küpers and Weibler 2005):

- Signal function
- Decision supporting function
- Behavioural function
- Cohesive function.

1. **Signal function**
   Emotions are expressed in different ways and manners. More than that, emotions are expressive tools and therefore a powerful communication tool. Understanding emotions can in this sense function as a signal to tell the organisation of information in the system. It has a feedback function but also potentially has a warning function. Understanding emotions will allow management to better tap into their employees and communicate at the same level and so increase the efficiency of an organisation.
2. **Decision supporting function**
   As we previously saw (see Sect. 2.6.2) our rational centres in the prefrontal cortex are directly linked to our emotional centres. Our orbitofrontal cortex is a great balancer of information and this information is processed consciously and unconsciously. By tying our emotions into decisions we are using more brain resources and using the power of a subconscious that can tap into much more information than the conscious can. When we talk of using emotions we do not mean being emotional i.e. using excessive emotions such as anger, fear or elation to make decisions—this is a recipe for disaster. Rather we mean use good common sense listen to your "gut"[6] and make well-balanced decisions.
3. **Behavioural function**
   Emotions affect the behaviours of employees. Either through their speed and efficiency but also through a mental preparation process whereby the work can be cognitively worked through and hence efficiency increased. As we have seen, emotions affect the hormonal balance in the brain and in the body and these will put the mind and body in an optimal state for whatever type of work lies ahead. In service industries the ability to deal with complexity may be in the forefront and in industrial contexts the ability to work efficiently but also to pre-empt any problems or disruptions will help improve working processes.

4. **Cohesive function**
   Emotion promotes in different ways the cohesion of a work force. The simple bonding and trust that is placed in each other and in leadership and vice versa. A longitudinal study in 2008 (Salamon and Robinson 2008) in the USA noted a

[6] There have been a number of books that have focused on gut feeling in recent years, the most popular being "Blink" by Malcolm Gladwell, 2005.

correlation between trusting workplaces[7] and productivity. Trust is in itself a key element of bonding. This will also help to reduce conflict, increase the level of communication and simply make the workplace a much more pleasant place to be. This in turn will affect and limit the stressors in the workplace and enable more people to work to their potential making work in general a more enjoyable experience. All workplaces rely on collaboration of some sort and the bigger corporations ever more so—these are driven by and need to have various components such as emotional bonding to make this a more efficient system. See also basic needs discussion in Chap. 4 and particularly attachment in Sect. 4.2.1.

In addition it should be noted that emotions and hormonal balances are also the key components of disorders and illness in many forms. Making the workplace healthier from the brain's perspective can only produce better results for the organisation and much of this is driven though the emotional systems in the brain. Organisations themselves can also increase the emotional bonding in various ways:

- **Rationalisation:** in being able to identify with the rationally formulated goals of an organisation we can stem irrational fears.
- **Projection:** fears and energy can be focused externally to competitors and markets.
- **Regression:** in the organisational network of organisations various hierarchical needs can be respected and rewarded.
- **Sublimation:** organisations provide a place to live out various energies that cannot be fulfilled in other contexts e.g. competitive instincts (towards competitors) which may cause conflict in family situations or in social circles.

2.8 The Power of the Limbic System

Neuroscientists have come to see the concept of free will in a different light. The whole concept of free will in itself has been questioned by Stephen Hawking (Hawking and Mlodinov 2010) amongst many others and what is certain is that a lot of free will is an illusion. This does not mean that we do not decide but rather that our decision making draws on underlying schemata we have laid down over the years an these unconscious processes colour and influence all our decisions. We know that rationalisation is often only a cover for our decisions.[8] Indeed that decisions are made in the brain before we consciously believe we have made a decision, on making a decision we then post-rationalise our decision. The limbic

[7] A more worrying side in corporate contexts is that the Harvard Business Review reported in 2006 that roughly half of managers do not trust their leaders—and 80 % of Americans do not trust corporate executives.

[8] There has been a lot of work on rationalisation starting as far back as 1931 with Norman F. Meier's now legendary rope trick. Nisbett's 1977 paper "Telling more than we can know: Verbal reports on mental processes" was a landmark paper and is still informative more than 40 years after being written.

system is responsible for this process—the emotional anchoring of processes and patterns that we draw on in the quick decision-making circuits that are all processed unconsciously.

Many scientists will argue that we may not have a free will but we have a “free won’t” and indeed we know that the cerebral cortex can influence the limbic system. The pathway is a two-way street. However this is significant for us in neuroleadership as we know that under stress and in fearful situations the functioning of the higher executive areas of our brain in the prefrontal cortex are suppressed and that we have therefore less of an ability to influence our limbic system and we then go back to our underlying decision-making processes and often our primitive survival reactions.

The dominance of the limbic system in our thought processes and decision-making ability is of key importance for organisations for if we want employees to learn new skills and behave in different ways we will need to reprogramme the limbic system and this is not an overnight process. Change is not a quick process but a consistent and focused process designed to change the underlying processing of the limbic system. We do know that everyone can learn, as the insights in neuroplasticity show, but we also have to understand how this functions and this functions with the limbic system and especially the reward system.

2.9 Neurochemical Processes

So far we have looked at the regions in the brain and some of their manifestations in function. Yet all of these processes are driven by the biological communication of neurons. This biological interaction is driven by chemical processes that are released between and in neurons. We therefore would like to briefly look at the chemicals in the brain.

Chemical transmitters in the brain are released in different regions and in different situations leading to and generating different feelings. We have already mentioned various hormones and transmitters such as dopamine in reward and attention and CHR at the start of the stress cascade. The feelings we perceive and feel are not merely brain functions but are primarily dependant on the excretion of certain chemicals and hormones in the brain and in the body in general. These transmitters in the brain have various functions, they can be inhibitory i.e. they inhibit the functioning of neurons or they can be excitatory i.e. excite and stimulate the function of neurons. As each cell has different receptors there can be different receptors for each chemical—this means that, for example dopamine can dock into four different types of receptor depending on the neuron and these have different functions, inhibitory or excitatory. It is therefore important to have a brief overview of some of the key chemicals in the brain and also a brief look into cognitive enhancement which has received increasing media attention in recent years.

2.9.1 Neurotransmitters and their Functions

The brain is a biological electrical circuit of incredible complexity and this circuit is driven by biological electrical processes which are stimulated by a host of different chemical substances. We will look at the four key transmitters in the brain that influence broad circuits and key functions. These are: acetylcholine, serotonin, dopamine und noradrenaline. These transmitters work in large networks of neurons and regions.

The **acetylcholine** system influences memory formation and is therefore important in memory performance. It also plays a role in sustaining attention (Perry et al. 1999).

The **serotonin** system plays a key role in mood particularly in fear and aggression (Duman and Canli 2010). Serotonin is also produced in the gut (90 % is actually produced in the digestive tracts) and thus it also gauges food availability (and is thus responsible for irritability and anger of, particularly, men when hungry). It has other wide reaching effects varying from influencing cardiovascular health to gauge of social situations, mating behaviours and gauges of social status.

The **dopamine** system is an extensive network that influences key areas in the brain and generates key feelings such as euphoria (see Sect. 2.5.2). The dopamine system runs from the limbic system to the prefrontal areas of the brain where our executive functions sit. It is therefore an important element of attention and ADHD is thought to have its roots in a lack of dopamine. Many ADHD drugs are dopamine supplements or boosters (such as Ritalin—see Sect. 2.9.2). In general it also serves as our reward drug inducing feelings of happiness and euphoria. On the negative side it also plays a role in compulsion (Van Winkle 2000). In combination with oxytocin it produces powerful bonding feelings.

Noradrenaline (or norepinephrine) is produced from dopamine and is responsible for the fight or flight response (Gerson et al. 2009) and its affects include increased heart rate, increased oxygen supply to the brain and muscles and release of glucose into the blood stream. It is therefore a key stress response chemical. It also plays a role in attention particularly with reference to realistic shift prediction (Van Winkle 2000; Corbetta and Shulman 2002; Devauges and Sara 1990). As with dopamine, lowered levels of this are implicated in ADHD.

There are currently over 50 substances that we know of that operate as transmitters in the brain. Drugs and medication can magnify, decrease or inhibit their influences. Here is a short list of transmitters and their actions (Table 2.1).

It is important to note that though these have been well researched in part, that the imaging technologies that we discussed in Sect. 2.5 show brain activation but do not give deeper clues to the actual chemical transmissions in these regions. For this there is much research done with animals to give us deeper clues as to how the various systems work.

2.9.2 Cognitive Enhancement

Casually known as “brain doping”, cognitive enhancement (technically nootropics) aims to improve the functioning of the brain particularly in the context of attention,

Table 2.1 Selected neurotransmitters (Based on Seidel 2004, p 132)

Neurotransmitter	Influence
Acetylcholine	Memory, attention
Serotonin	Fear, decision-making, mood
Noradrenaline	Energy, mood, attention
Dopamine	Feelings of reward, attention
Endomorphin (or Endorphin)	Well being
Oxytocin	Trust, love
Corticosteroids	Stress, anger
GABA-deficiency	Fear disorders
Testosterone	Dominance, aggression

energy and memory consolidation through taking specific chemical supplements and/or medication (Auf dem Hövel 2008).

The use of such cognitive enhancers has drastically increased in recent years. In 2007 a study (Sahakian and Morein-Zamir 2007) noted that 7 % of students at college (in the USA) had used cognitive enhancers to achieve an edge in the year preceding the study and on some campuses the figure was as high as 25 %. According to a study in Germany in 2009 (Krämer and Nolting 2009) over two million people have already tried such drugs and 800,000 use them regularly. There has also been much publicity in the press. For example the *New Yorker* ran an article in 2009 (Talbot 2009) focusing on undergraduates and academics at universities. Further articles have appeared in the *New York Times* and *Time* to name but a few.

These cognitive enhancers unlike the classic boosters coffee and tobacco, specifically target various transmitters and hence brain regions and specific effects such as increased attention. Many of these drugs were originally developed to treat sicknesses such as Alzheimer's and ADHD and are now seen as tools to increase performance (Table 2.2).

The above are some very specific enhancers and there are however a whole host of others that have their roots in dietary supplementation and sports performance, NAC, alpha GPC but also creatine and L-carnitine have well documented research showing their impacts in the brain (Rae et al. 2003). For example, the amino acid L-Tyrosine is a precursor to dopamine and norepinephrine and hence can operate in a similar way to dopamine enhancers.

However there should be a healthy dose of scepticism here. In looking into the brain in neuroleadership our goal is to look into how the brain functions and how these can best function with this we include a healthy chemical environment in the brain. A healthy brain and a healthy environment indeed will produce a healthy chemical environment within our cranium. Using drugs to try to counteract an unhealthy environment is not a solid solution. Healthy food and healthy eating and sleeping habits will do more than any single chemical to balance the brain. Indeed in Sect. 2.9.1 we noted that 90 % of serotonin is produced in the gut and unhealthy eating habits will also influence the production of serotonin in the digestive tract. The brain derives its energy from glucose and the long-term release of good quality glucose will influence our brain functioning as will a ready supply of micro- and

Table 2.2 Popular cognitive enhancers

Methylphenidate	**Methylphenidate** is the key component of Ritalin that is used to treat ADHD. This is increasingly being used by students, scientists and managers to increase their ability to concentrate. Methylphenidate increases the levels of dopamine and noradrenalin in the brain through inhibition of the reuptake receptors and this can lead to improvement of mood (to euphoria) increased concentration and inhibition of hunger and drowsiness but with a potential loss of the sense of reality.
Donepezil	**Donepezil** is marketed as Aricept for the treatment of Alzheimer und dementia. Donepezil influences the function of the stimulatory paths of nerve cells and improves cognitive and memory processes.
Modafinil	In 2008 Provigil was re-classed in Germany as a prescription drug and no longer a controlled substance. In the USA, Canada, Australia and the UK is a prescription drug. **Modafinil** is licensed as a drug to treat narcolepsy, sleep disorders and daytime drowsiness. For this reason it is often used by students and managers. It was also thrown into the press spotlight with various sports doping cases. It was listed in 2004 as a prohibited substance by the World Anti-Doping Agency.
Adderall	Is a prescription drug only available in the USA and Canada but has had increasing press as a neuro enhancer. It is used against ADHD and narcolepsy. It operates by increasing the amount of dopamine and norepinephrine between synapses by inhibiting their reuptake in the brain.
Piracetam	Has widely reported cognitive benefits though rigorous scientific findings are still scarce. It increases oxygen consumption in the brain and ATP (cellular energy source) metabolism. It has been shown to improve cognition in dementia patients and other cases such as impairment from alcoholism and autism. It is widely available in the USA, Europe and other regions globally without prescription. Piracetam is part of the racetram group of substances—many used as cognitive enhancers.

macronutrients. Trying to redress the balance in the brain with some chemicals may be attractive but in the long run may be counterproductive particularly if the brain and body then come to rely on these.

However, this said, the rise of cognitive enhancement seems to be pre-programmed. After all with the demand of the workplace quick and easy fixes are certainly very attractive to many in the corporate environment if not to employers themselves. The increasing challenge in the modern workplace are also likely to drive more people to these enhancers.

Figures from the "DAK Health Study 2009"(DAK-Gesundheitsreport 2009)

43.5 % of the respondents know that taking drugs against age-influenced brain disorders, memory impairment and depression can also be effective for healthy people.

20.3 % of respondents stated that for healthy people the risk of taking these medications in relation to their benefits is acceptable.

21.4 % respondents said they had been recommended to take drugs to improve their cognitive abilities of their mood (the majority of these

(continued)

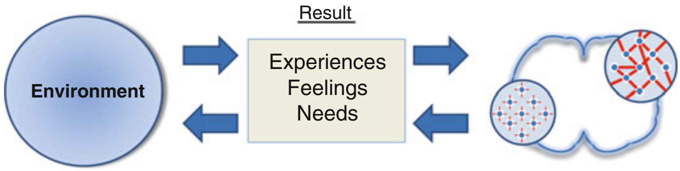

Fig. 2.17 Interaction between brain and environment

recommendations came from friends and relatives but also from the medical community).

Experts rate the factors influencing the consumption of these drugs as, amongst others, increased time pressure, emotional work and competition in the workplace.

2.10 A Brain-Friendly Environment

Given the information we have just covered we can see that there are a host of influencing factors that impact the brain. Indeed the environment and our interaction in this environment are constantly causing the brain and the neurons within this to fire in specific patterns. We therefore know that behaviour and experience forms the connections in the brain. We also have learnt that fear and negative emotions are bad from the standpoint of brain biology and that reward centre activation is positive. These are of crucial importance for us to understand as neuroleaders. They are crucial because little thought is given in business to a healthy brain environment—it is left to chance. And if the team interactions and the business environment happen to be positive so the impact on the brain will also be positive. Yet this can also change, by chance. The business environment can change, market conditions can change, new competitors can come into the market, team members can and do change as do members of the leadership team. These can then destabilise the context in which these brains are functioning and what was previously, by chance, a healthy brain environment will slip into a negative brain environment. The stakes are even higher than that because when times are tough that is precisely the moment that we need our brains to be operating at their optimum. Leaders often grapple in the dark here for solutions or switch to bad habits which can lead to a negative reinforcement cycles and lead to badly functioning brains but also physical stress, and in cases, severe clinical stress. This is bad for any business and costly too in terms of revenue lost, productivity lost let alone the personal human cost.

The knowledge we give here and specifically in Chaps. 4 and 5 are designed to enable you to create environments that are healthy for brains in business with all the positive consequences of this. The positive consequences are brains that can operate at their maximum ability: to be productive, creative, intelligent, reactive, flexible and open to change. This interaction between the environment, though, is continual.

The environment affects the people in the environment, and the people in the environment help to form the environment. The interaction in the environment creates the atmosphere and moods in the context and the perceptions of individuals may lead to different interpretations and hence also have an influence on the environment. Everything is connected to everything. It is a continual exchange back and forth. With time this will also rewire the brain in specific ways (see Fig. 2.17) we will approach this in more detail in Chaps. 4 and 5 after we have looked at some of the other key protagonists in the field of neuroleadership.

2.11 Summary

- **Neuroscience** includes a wide variety of disciplines that study the nervous system in general and specifically the brain including, amongst others:
  – **Neurobiology:** study of the structures, functions and development of nerve cells and the nervous system.
  – **Neurochemistry:** study of the chemical processes in the nervous system.
- The **brain** can be split into **three regions**:
  – **Brain stem:** instinctive reactions, reflexes and homeostasis
  – **Limbic system:** emotional centre
  – **Cerebrum:** higher forms of information processing
- Brain cells, **neurons**, consist of a cell body, axon and numerous dendrites
- **Plasticity** is the ability of the brain to keep building new connections (and hence continue learning)—this is possible for most of human life.
- The **reward system** is a system of structures in the limbic system that process reward and the feeling of happiness that this generates. These produce specifically the hormone dopamine that affects our feeling and also drives attention and learning.
- **Fear** stimulates the **amygdala** in the brain and also inhibits cognitive function and increases negative bias. Fight, flight and freeze are primitive instinctive dear reactions. The **HTPA axis** is a chemical stress cascade in the body.
- There are numerous methods of looking into and researching the brain. **fMRI** is the predominant method as it enables us to see what parts of the brain are activating and new methods are also enabling us to see the connections. This gives us concrete insights into the structural communication and functions of various regions.
- **Cognitive enhancement** is the targeted improvement of brain performance through drugs and supplements that are designed to increase, for example, attention, memory or energy.
- The brain can and does **change** but the environment must be suitable and the reward system needs to be activated.

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