

7 How the brain works

If we are to really understand how to invent anything, we need to go back to basics in thinking as well as in science – and that means understanding something about how the brain works. Thinking about that blob of grey matter inside your skull can be rather disconcerting, but we will not be side-tracked by metaphysical debate; if you have private views on spirituality, we will not be challenging them. Suffice it to say that if there is a human spirit that inhabits or constitutes our minds, it is way beyond the simple science of synaptic connections.

If we were to present our descriptions of the brain to experts, whether they were brain surgeons or psychologists, there would be many challenges, particularly of the kind ‘but it is much more complex than that!’ However, we are not trying to get you to be brain surgeons or psychologists. We are describing the brain in a simple way so that you can understand enough about how it works to use it in different ways for different purposes. Even if all you do is realise that you can change how you are thinking and move from focusing-in to crazily-creative and back again, and do this with a sense of purpose, then we will have achieved our aims. It is your machine, so use it!

A quick history of brain science

The brain is, in many ways, the last frontier of modern medicine and despite many years of research much of its functioning is still something of a mystery.

Beginning our history with the ancient Egyptians, the brain was not thought to be very significant for the journey after

mummified death, and their embalmers scooped it out down the nostrils and threw it away. The Greeks had a greater regard for the brain, knowing that this was the place where thinking occurred, although they concluded that the mind and spirit existed in the internal cavities of the head. This inextricable mixing of body and soul continued until Descartes, the seventeenth-century philosopher and mathematician (founder of Cartesian logic), concluded that the physical body and the metaphysical mind/soul were separate things.

The brain started to get more attention in the Renaissance from such notaries as da Vinci, who mapped much of the human body, and in the eighteenth century, along with the discovery of electricity and Galvani's experiments with frog's legs, the nerves were identified as 'wires in the body'.

By the mid-nineteenth century, the functions of various parts of the brain were beginning to be identified, often through observing the location of brain injuries and the resultant impairment. Other discoveries came through gruesome experiments, such as the removal of a dog's cortex to show that it could still walk as the motor parts of the brain were lower down.

Even in the modern day, brain surgeons still find their way around by prodding bits of the brain and asking the conscious patients what they feel. Although they know approximately where many functions lie, they do not know *exactly* where, and a short distance can separate very different motor or cognitive areas.

The real parts of the brain

The brain is made up of three main parts: the cortex, the limbic mid-brain and the primitive lower-brain. The bit that we usually envisage when we hear the word 'brain' is the cortex. This is the big crinkly walnut at the top that often features in biology lessons and science fiction films.

The cortex does a great deal of processing, most of which we are entirely unaware. It is a curious paradox that although it seems like this is the part that makes we humans very

intelligent, if it gets damaged it often seems not to have much effect! It is highly connected to all the other parts of the brain and interacts frequently with them.

You might think that if it does all this processing of information then what it does reflects mostly the input from our senses. But the latest research suggests that in fact what it processes is as much influenced by what the other parts of the brain suggest should be there as what actually is there. In other words if you so strongly believe you will see a ghost (or your partner when you are out on an illicit date!) then that is what you will see. In fact, in order to cope with the complexity we have to deal with, it seems likely that the brain is constantly predicting what you see and processing what it thinks you will see before you really see it. We live mostly in the world of our imagination and only when the real data coming in hits us very hard will we take that much notice of it. This helps to explain why creativity can be difficult without help: you do not even see the creative idea because you are not expecting it.

The rest of the brain is made up of a number of individual parts, some quite small, although size is not an indicator of importance (see Figure 7.1). These parts are smaller than the cortex but are much more susceptible to damage. You can think of these as the main process managers. If they go wrong you are in trouble.

The limbic system or ‘leopard brain’ contains emotional controls and basic reactions such as the fight or flight response.

Below the leopard brain is the more primitive ‘lizard brain’ which controls basic functions such as breathing, digestion and circulation. To make a nice set of three ‘Ls’ the upper cortex gets called the ‘learning brain’, reflecting that this is where we consciously think, learn and create.

Some, but not all, of the more interesting parts of the mid- and lower-brain are described in the following sections.

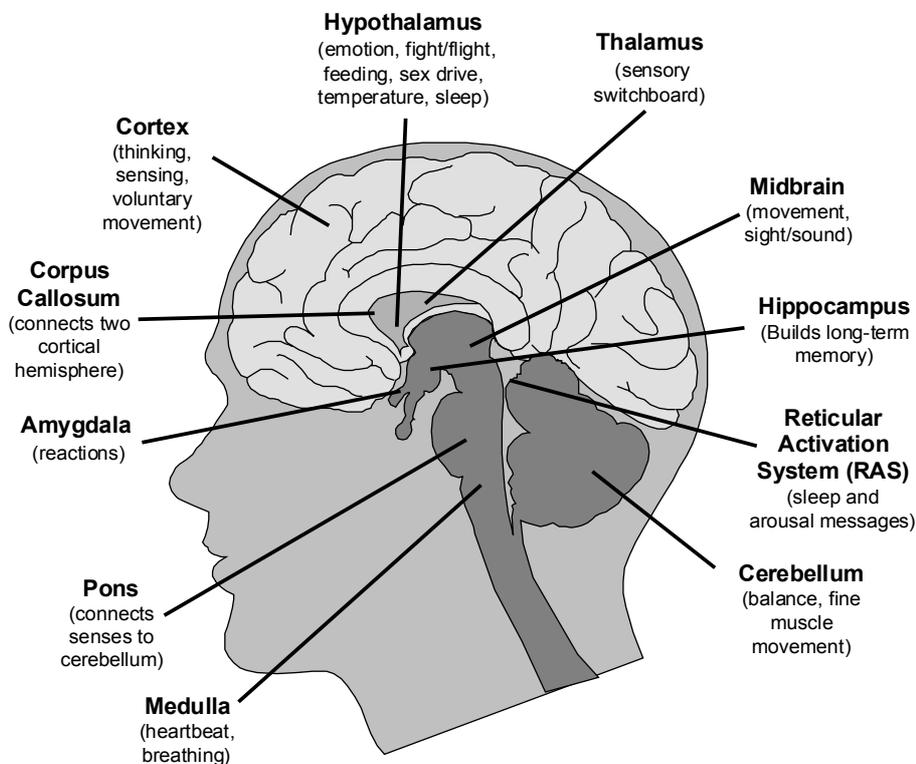


Fig. 7.1 Bits of the brain

Hypothalamus

This is a little powerhouse in the middle of the brain which houses many of the basic animal drives, including the ‘four Fs’ of feeding, fighting, fleeing and fornication. It is also affects temperature control, sleep and emotions.

Being outside the cortex means that all of these potential inhibitors of creativity are outside of our direct conscious control, and can (and do) interrupt us at the most inconvenient moments.

Thalamus

All senses except the sense of smell, which goes straight into the brain, pass via the thalamus, which acts as a form of

communications centre, passing information to various parts of the cortex. The route from the outside world to our conscious perceptions of them is by no means direct.

Hippocampus

Long-term memories do not go directly to the cortex, but are laid down by the hippocampus. It does this by replaying experiences to the cortex, including in dreams.

Amygdala

This little button-like system acts as a bypass to the conscious mind, causing us to react unthinkingly to such situations as a falling branch or child tumbling into a river. When people say, 'I just didn't think about it,' they are probably right. It also drives many of our fears, causing primitive and phobic reactions.

How we think: patterns of the mind

The basic cells of the brain are called neurons, of which we start life with about 100 billion, which is quite a lot. This is just as well, because we then proceed to lose about 100,000 of these each day for the rest of our lives. That adds up to about 37 million per year and around 3 billion over a lifetime. Older readers will be delighted to hear that this is a long way from being the main cause of any senile decay. In fact our creativity and intelligence is not so much connected with the number of neurons we have at any one time but, as we shall see, *what we do with them*.

Reaching out to communicate

Although they come in many shapes and sizes, a magnified single neuron (Figure 7.2) looks like an alien from another planet. From its central cell body, an *axon* stretches out as a long-distance nerve fibre, communicating with other neurons, muscles or glands through its set of *terminal buttons*. Other

protuberances are called *dendrites* which reach out to listen to other neurons, ready to connect up in the vast Internet of the mind.

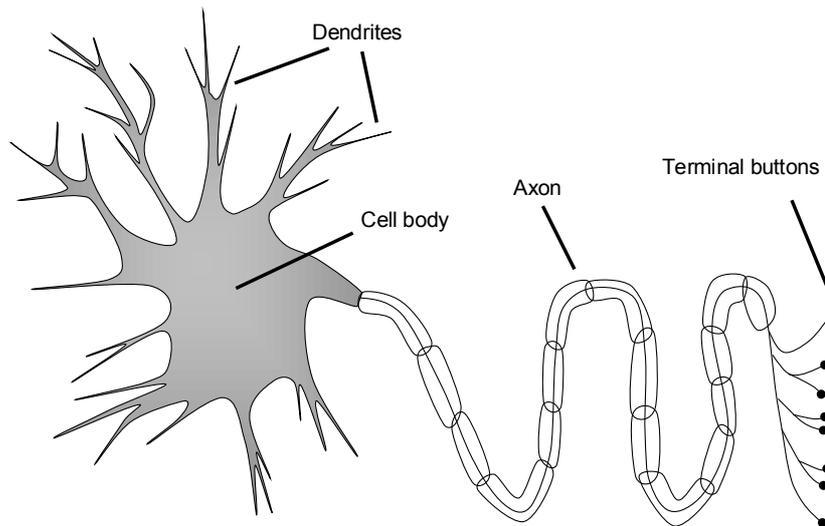


Fig. 7.2 A neuron

Neurons communicate with one another through a combination of electricity and chemistry. A neuron at rest has a net negative charge. This attracts the (mostly) sodium ions outside the neuron into it. This causes another change which results, about one millisecond later, in the ions being pumped back outside. The voltage on the cell thus swings up and down and is the ‘firing’ that is the basis of communication between neurons.

When a terminal button of a neuron gets close to the receptor areas on a dendrite of a second neuron, it does not quite touch, but leaves a gap known as a *synapse*. When the first neuron fires, the electrical charge causes little containers in the terminal button called *synaptic vesicles* to expel the chemical they contain across the synapse and into *receptor cells* on the second neuron, as in Figure 7.3.

There are two types of chemical that can be transmitted across the synapse: *exciters* and *inhibitors*. Exciters stimulate the second neuron, increasing the chance of it firing, and

inhibitors decrease the chance of it firing. If the second neuron fires, then it will stimulate a further chain of neurons to fire, creating a thought pattern in the brain.

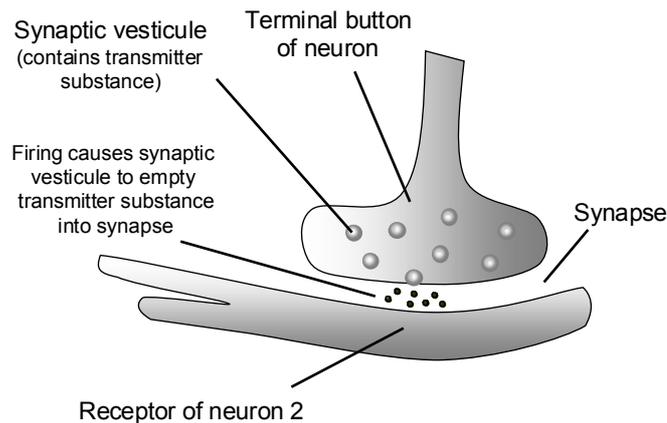


Fig. 7.3 Neurons connecting

There are various chemicals that are used as transmitter substances, such as acetylcholine and norepinephrine. Just to complicate matters a little, a single chemical can be either an exciter *or* an inhibitor, depending on where it is being used.

Just for interest, mind-altering drugs often work by playing around with these neural synaptic connections. Cocaine and amphetamines, for example, prevent the re-absorption of norepinephrine, resulting in an extended period of stimulation as the brain fills up with incomplete synaptic transmissions.

Thought patterns

Thoughts, then, are simply long sequences of synaptic connections across chains of neurons, as each firing either excites or inhibits further connections. If you could attach little light bulbs to each neuron, you would see something like a non-stop thunderstorm of lightning flashing and flickering across the surface of the brain.

So with all this connecting, how do we learn? How do we remember things? Very simply because once a terminal button has fired against a second neuron, it becomes more likely that it will fire next time. Think of it like hot ink sloshing over a gently tilted waxen surface (see Figure 7.4). The first time the ink runs, it takes a random course, leaving a little bit of a depression behind from the path that it took. Next time, different routes may be taken, but maybe a little more of the ink runs down the shallow path that has been eroded. When you repeatedly think about the same thing, the channel gets deeper and deeper each time it is used.

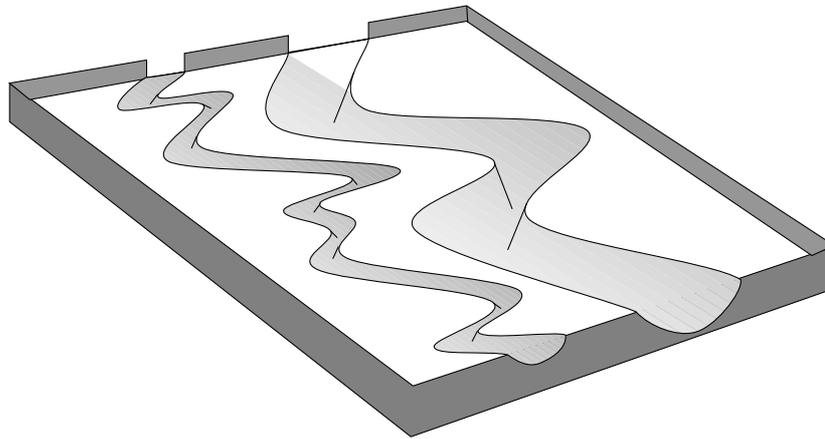


Fig. 7.4 Repeated thoughts are like channels in the mind

Before long you have a repeatable thought that is easier and easier to make. This is what learning and memory is. Virtual grooves in the brain from patterns of thought and perception are what enables us to repeat experiences, using the things that have worked best for us in the past.

In practice, the landscape of the brain is more complex than the wax example as multiple pathways can pass through a single neuron and one neuron can fire more than one subsequent neuron. A single neuron can thus take part in many thoughts, resulting in an almost infinite number of possible thoughts and memories.

A new thought, then, is quite a significant event, as it is too easy to fall into pre-formed mental patterns. Being creative and inventing things is about thinking differently, of forging patterns where there was none before. As biochemist Albert von Szent-Gyorgy put it, 'Discovery consists in seeing what everyone else has seen and thinking what no one else has thought.'

An important point to remember from this is that the brain works by *patterns*. Whether it is patterns of recognition or patterns of behaviour, the past pathways tend to lead future responses, which is a critically important reason why creativity and innovation can be so difficult.

Memory patterns

When we commit something to memory, it is held as a potential pattern, a burning of a pathway across the brain (see Figure 7.5). This is basically how we learned our multiplication tables: as we repeat 'two times two is four' the pattern gets burned deeper and deeper every time, until all we need to hear is 'two times two...' for the start of the pattern to be found and '...is four' is simply a continuation to completion.

Things get a little more complex when we visually recognise a friend. When remember a person's face or any other object, we do not remember it just as a fixed block of colours, but as a pattern. Seeing Jane with our stereoscopic vision, from multiple viewpoints, we remember the pattern formed by the relative sizes and positions of her major features. We can then still recognise her when her face is distorted into different expressions, when viewed from different angles and even when she is partially obscured, such as when she is standing behind a lamp post.

You can easily test this. Think of someone you know well. Now try to recall the detailed shape of their mouth or nose. Then go and look at them to test your memory: the chances are that you will not be entirely accurate, even though you may have known them for many years.

This is also why children draw people with large eyes and stick bodies: they are drawing the pattern they are perceiving, rather than the actual visual image. Even as adults, our pattern memories prevent us from drawing what is really there unless we are taught to look beyond our clever, but limiting system of mental patterns to the real patterns of hue, contrast and light.

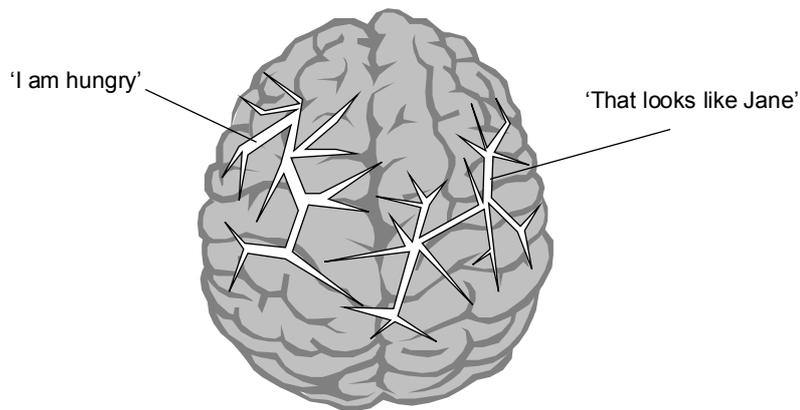


Fig. 7.5 Thought patterns

The ability to remember facts is often associated with intelligence, but such activity simply involves saving and recalling patterns. Creativity is a different kettle of fish, as this requires us to create new patterns which make up our new, original thoughts. Although our creativity increases with intelligence (possibly due to increasing ability to use our brain), it is not unknown for it to drop off at higher levels of intelligence as experts become trapped by predefined systems of knowledge and reasoning.

In the end, we only have two things we can use to innovate: the mental patterns – the grooves of thought and experience stored in our memories – and the way in which we manipulate them. Manipulation of our minds also requires in turn new mental patterns of thought. This book aims to give you those thoughts so you can use what you already know to invent what you really want.

Left-brain, right-brain

The ‘learning brain’ cortex of the brain is not uniform in its use and different parts get used for different functions, such as speech and motor control (which is why brain damage can have different debilitating effects). This is accentuated by the way the cortex is divided into two halves, connected only by the bundle of nerve cells called the *corpus callosum*. Roger Sperry received a Nobel Prize in 1983 for his work that showed how these perform different functions. Where the left hemisphere deals more with language, logic and detail, the right hemisphere deals more with patterns and wholes.

The work of Sperry and his colleagues has led to the useful notion of ‘left-brained thinking’ as cold and logical and ‘right-brained thinking’ as emotional and creative. Thus the ‘analytic’ invention methods of Chapter 1 can be seen as left-brained and the ‘creative’ methods of Chapter 11 as right-brained. A caveat to this – this is only a tendency and the divide is not as clear as some would have you believe. Nevertheless, there is some truth to it and it can be a useful thinking model.

Classification: making sense of the world

To understand the workings of memory better, particularly with regard to innovative thinking, let us go up a level or two, shifting gear in order better understand how we make sense of the world around us.

Chunking the world

When a baby opens its eyes, its brain is swamped by the riot of colour in the world around it. To understand this complexity, it gradually learns to break the world down, encoding it into separate chunks of information. Mother, father, food: each gradually comes to be recognised as a distinct and individual chunk of information.

We continue to manage the world's complexities by creating hierarchies of chunks. A leaf is on a branch, which is on tree (Figure 7.6). Thus we can focus in on our mother's fingertip or hand, or chunk out to see the whole person as a single entity.

We can make deliberate use of this ability in innovation, for example by chunking down into the detail of the problem or chunking up to see the big picture. By changing our perspective, we see different things about the situation.

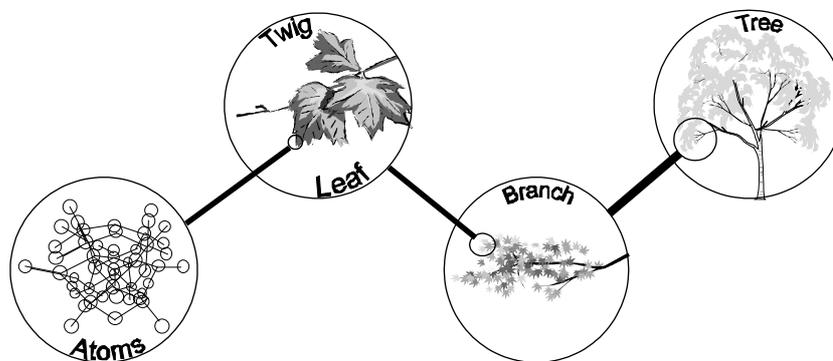


Fig. 7.6 Chunking levels

Languaging chunks

Words are perhaps the ultimate chunk, with each word *representing* a predefined chunk of experience. Words set us free but they also ultimately constrain our ability to communicate and describe the world around us.

Words helps us differentiate, sometimes in subtle ways, between chunks of information, and the language we use is indicative of our experience. For example, Eskimos have a number of different words to describe snow. There is also a native American tribe which has a single word for both 'blue' and 'green', and as a result of this is they cannot distinguish between these two colours: they simply are seen as shades of the same colour.

When we experience something new, if we cannot describe it with words, then we will have difficulty in making sense of it.

Creating a new word is a significant event that effectively says, 'This is so different and important we need to mark its existence with a new symbol'. It is also why new inventions are often given new made-up names.

Words are so important for describing, we even think with them. Our self-talk and dreams contain endless inner conversations as we ruminate about the world around us and plot how we might better cope with the outer confusion.

If our vocabulary is small or our ability to use words is limited, then this can also limit our ability to manipulate the verbal chunks that describe our experiences and hence constrain our ability to use them to create new combinations and concepts.

Short-term memory

Our short-term memory contains about seven 'slots' each of which can contain one chunk of understanding. Items in these slots have a very short life-span: have you ever been introduced to a person and then forgotten their name moments later?

Short-term memory is primarily verbal and phonological, where each chunk is represented by a sounded word. This has been shown by experiments where short-term tasks have resulted in confusion, for example between 'pear' and 'fair', but not between 'pear' and 'peach'.

When we are dealing with new or complex concepts, short-term memory very quickly becomes overloaded with details that we have not yet learned to combine into larger chunks. We often do not realise this when we are describing new ideas to others: these people cannot yet handle the ideas as single chunks and so must break them down into more fundamental components, only a few of which can be processed at one time.

Long-term memory

By the time things get put into long-term memory, they have often received a significant amount of processing to extract patterns and create meaning. A key type of long-term memory

is thus sometimes called *semantic* memory to reflect the fact that it contains our interpretation of the real world, not what is really there. We also have *procedural* memory for 'how to' skills, *fear* memory for phobias (stored in the amygdala) and *episodic* memory which contains short movies of significant actual experiences.

It is worth keeping this in mind when we recall things from memory, that the chunks we recall are not necessarily what is true, even though we treat them as being complete and absolutely correct.

An effective long-term memory for creativity is one from which we can recall thoughts with reasonable ease. By learning to remember well we can build a greater resource which we can use to stimulate new thought, although a mind that is too tidy can be detrimental if it will not entertain thoughts that do not fit into its predefined classification system.

Class-ification

When I see a pattern of a long, irregular vertical stem with smaller stems off it, I easily interpret it as a tree. This is very useful as it saves me from having to remember a separate chunk for every tree I see. Now I can recognise an *instance* of the *class* I call 'tree'. I can also create a hierarchy of classes, recognising oaks, beeches and sycamores each as a *sub-class* of the class of 'tree' and 'plants' as a *super-class* of tree.

This ability to see the basic patterns in similar items and consequently create generalised descriptions enables us to significantly reduce the chunks we would otherwise need to understand and manage our world.

When we do not have an appropriate classification box, then we have to either create a new box or approximate to the closest match. Creating a new box is a big thing as it disturbs the pattern of boxes we already have and admits that our previous system of knowledge was less than perfect. Too many boxes can also undermine the basic advantage of classification in the way that it simplifies our world. How, then, do we handle situations which do not fit into one of our existing boxes?

Fortunately, we are pretty good at ‘fuzzy’ matching, fitting our experiences into a ‘good enough’ box, finding patterns that do not match exactly, but are sufficiently close to be acceptable.

Much of learning is about creating new classification boxes, along with appropriate rules for recognising and dealing with their contents. As our learning slows, we create fewer new classifications and we eventually may even forget *how* to create them. Creative people tend to have a large and expanding number of classifications, primarily because they never stop learning and finding new ways of viewing the world, out of which they can derive even more new ideas.

Rapid classification

We tend to have a desperate need to classify everything we experience. When I meet you, one of the first tasks I set myself is to push you into one of the boxes I keep for classifying people. Within seconds you will be in a box marked something like ‘arrogant-and-alooof’ or ‘mother-earth-type’. Once you are in the box, if you try to get out, I will work hard to push you back in.

Although such classification systems enable us to simplify the massive level of complexity that we face in the world, our need to classify everything we experience can prevent us from seeing things in different ways. As Einstein said, ‘A great thought begins by seeing something differently.’

The speed with which we classify our experiences will depend to some extent on our needs for control and certainty, as discussed in Chapter 8. When something is unclassified, it is uncertain and potentially threatening, so we move away from the uncertainty and into the nearest classification. If this is wrong, our deep need not to appear wrong (another block to creativity) makes us reluctant to change the classification, dooming us to a lifetime of misunderstanding.

Creative people tend to be slow to classify and are relatively comfortable with uncertainty. When they stand at the junction of such a decision, they look carefully down each classification road or even out into the undergrowth, exploring possibilities of

descriptions off the beaten path. They may also put off the decision, exploring each path in turn or coming back later to peer and ponder.

Big patterns: mental models

The way we create internal patterns of the outer world stretches to complex models of behaviour and the whys and wherefores of how things work. A *schema* (plural *schemata*) is an internal pattern, a large-scale classification that contains many generalisations and assumptions. A friendlier term that we will adopt, first used by Scottish psychologist Kenneth Craik, is *mental models*.

For example, we have a mental model for each different nationality: the French may be assumed to be self-absorbed, romantic connoisseurs of good food and wine, while the Germans are taken to be arrogant but with a great eye for detail. This makes it much easier for us to decide how to deal with different peoples, even though the biases embedded in our schema may make this interaction inevitably unfair.

A mental model is a larger-scale pattern of understanding of the world, and may contain other models, classes and objects. These big pictures guide much of our interpretation of the world around us and can enhance our creative ability, but more often act to constrain our thinking.

Mental models are where we hold our learning. We experience the world, spot the patterns and then slot them into our mental models. A particular trick that we do after the ‘aha’ we experience when we learn something is called *closure*, where we effectively close the door on the mental model. After this, when we see something that will fit that model, we just say ‘oh, it’s just one of those’ – that is, we *stop learning*. Because we can approximately fit an experience to the model and this is sufficient to enable us to predict what will happen, we ignore any further detail. It then often requires an unpleasant surprise for us to reopen the door to improving the model.

A simple technique for creative and inventive thinking is to stand back and recognise that we are using these imperfect

mental patterns. When we realise what we are doing, we can then challenge the assumptions and generalisations held within the mental models.

Association: just like that

Classification helps up break things up into recognisable chunks, but we also benefit from stitching these chunks back together again, for example stringing words together into a sentence or remembering that flashing lights are often found on police vehicles. As we have discussed, our brains are a network of connections, not a set of pigeon-holes, and as such we have a powerful ability to think in highly connected ways.

Neural networks

Think of elephants. Then watch where your mind goes, through other associations you have with the word. Do you recall trips as a child to the zoo? Or Walt Disney's *Dumbo* or various jokes? Memories can be related in many ways, often from experiences or through secondary links, such as when elephants remind me of tigers, because a tiger scared me soon after I saw my first elephant at a zoo.

Figure 7.7, where the thicker arrows represent more likely thought associations in the mental landscape, illustrates some of the effects of such networks. Likely thoughts may come from repetition, but these deep valleys can also be cut in a single slice by traumatic experience, such as the 'elephant-zoo-tiger' link. Thoughts may be deep hollows in which we can arrive from many directions, such as 'Africa'. They may also be mountains, from which we can easily roll downhill in many directions, such as 'grey' (they can even be both at once!). Associations can be one-way or two-way, with a different thickness of arrow in each direction. The associations we have recently made may affect our choice of the next association, so 'elephant-musty-smell-horses' may be likely but 'zoo-musty-smell-horses' may be unlikely.

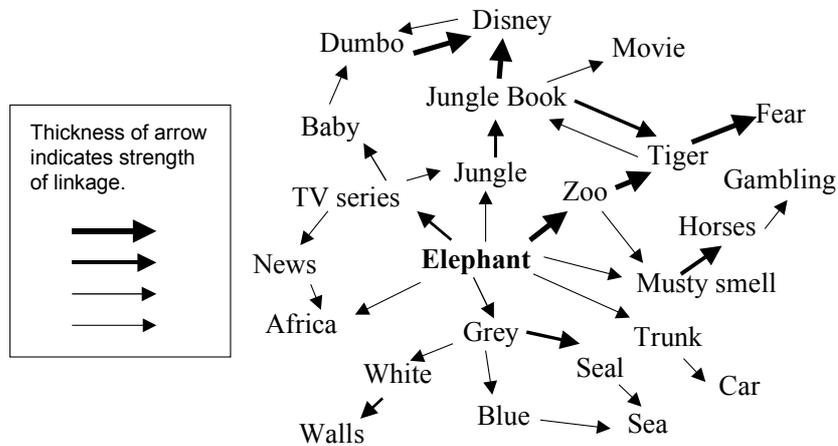


Fig. 7.7 Linked memories

One of the traps of creativity is that we start digging for gold, looking for an idea, and then get stuck in the hole as each new idea is constrained to be closely associated with the problem. Association keeps us in the hole and it can also lift us out, if only we loosened the bonds a little. This naturally jumbled linkage of thoughts is a gold mine of stimulation that we can deliberately use to leap and link to more distantly connected thoughts and hence to new ideas.

Just like that

If I see a plant I have not seen before, to create a new classification I typically start with plants I know which are similar to the new plant. New classifications are often held as ‘like A but with differences X, Y and Z’. A zebra is like a horse with stripes. An eel is a cross between a fish and a snake. Jane looks like Susan, but with black hair. This makes classification easier, although this connectivity can cause problems: if I change my understanding of horses, should that also change my understanding of zebras?

When we understand things in terms of other things, we are using analogies and metaphors. The use of metaphors is so common, we often do not realise we are using them, for

example when we say an experience was ‘brilliant’, we do not mean it gave off light. At its most extreme, every word is a metaphor, as the word is a representation, not the actual thing.

The question, ‘What’s it *like?*’ is a powerful tool for bouncing ourselves out of uncreative holes. If I were trying to come up with ideas for a home security business, I might think start with, ‘A person’s home is their castle’ and then link to ‘It’s like building an impenetrable wall around the house,’ which could lead me to thoughts of toughened glass or a secondary toughened door (the ‘portcullis’) that comes down behind the normal door.

Associated emotions

When we commit something to long-term memory, the associations of the context in which we experienced it often get saved alongside it. If we remember a concert we went to, we may also remember details of the people around us, the sound of the music, the smells in the theatre along with the emotions we felt. If I saw a friend just after witnessing an accident, then thinking of the friend is likely to drag along the memories and traumatic feelings about the accident.

One of the unfortunate effects that this has on innovation is that we may well associate having creative new ideas with being told off as children (or even as adults) as we are taught to conform to strict social norms. As a result of this, creative thoughts can be associated with feelings of guilt and repression, resulting in rejection not only of our own ideas but also those of others. We seldom do this consciously or even remember the original incident.

If we do not take steps to understand and release the trauma of our past, it will follow us around like a trail of tin cans, clanking inconveniently and tripping us up when we least need such disturbance. These bad feelings are very good at protecting themselves: consider how the notion of psychotherapy or counselling of some sort is alien and frightening to many people, despite the fact that taking time to look inside yourself can be a powerful creative tool. The first step on this path is to

gain a greater understanding of how we work and how our inner mental systems can help or hinder inventive thought. This chapter of the book, although not a definitive tome on psychology, is intended to help you along the way.

Invention so-what

So what have we learned in this chapter that will help us invent? Here are some of the key points to remember:

- If the primitive parts of your brain are in control, you cannot invent. Fear is a big creative block. Even desire may get you only what you want to see.
- If you have thought about something a lot, you are likely get stuck. Inventing often means breaking out of thinking ruts to make new thought patterns.
- Thoughts link together. The more thoughts you have had, the more thoughts you can have. *Any* thinking exercises or new experience is good for developing the ability to invent.
- Breaking things down into smaller chunks is a simple and natural principle for seeing things in different lights. Great inventions can come from changing just small parts of things. You can also chunk up to change concepts and purposes.
- We think in words. A larger vocabulary will enable you to understand more things and hence use them in invention.
- Do not try to take in too much at once: your short-term memory is a bottleneck. Creating concepts and models in larger chunks is a good way of handling bigger things.
- Avoid generalising what you see: find many ways to classify things. When things do not fit easily into one of your little classification boxes, neither push it harder nor ignore it. Just hold it and wonder about it.
- Find ways of understanding things: build lots of mental models. Each model is a lens which can be used to examine the world either from a different viewpoint or in greater detail.

- Build links between your thoughts, making unlikely associations that can lead to good ideas from many places. Ask ‘What’s it *like?*’ to get off the beaten path and find those weak associations.

Watch out for emotions! They come attached to many memories and thoughts, and can lead to the lower brain taking over our better judgement.