Your Wonderful Brain

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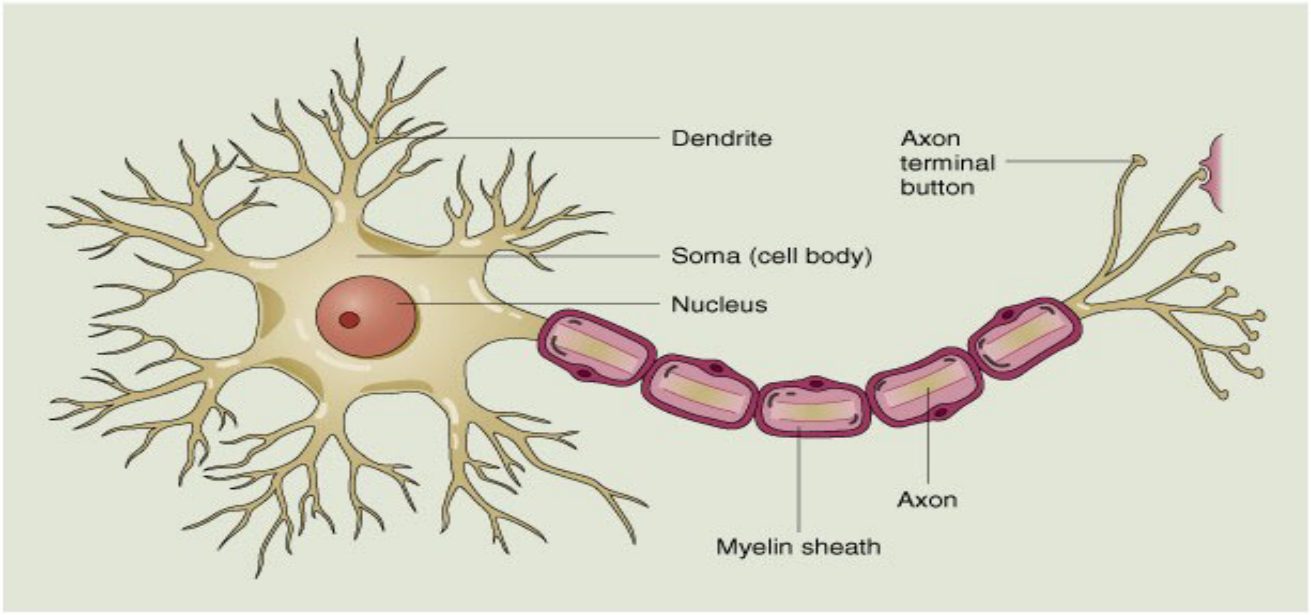
Introduction

This is a summary of the key features and functions of your brain. For more information, check out the resources on the WiseBrain website.

Complexity

Although your brain isn't heavy - about three pounds of soft, gooshy tissue like tapioca pudding - it has about 1.1 trillion cells altogether. One hundred billion of those are in the "gray matter," a kind of "skin" of nerve tissue wrapping around the "white matter" that comprises most of the bulk of the brain. The gray matter is where most of the action for conscious experience takes place.



When a neuron fires, sending neurotransmitters across the synapse – the tiny space between it and another neuron it is connected with – that either excites or inhibits the receiving neuron. To simplify a little, the sum of all the excitatory and inhibitory signals a neuron receives from its "upstream" neurons determines whether it will fire itself – sort of like the dominant message from a crowd of people all shouting "go!" or "stop!"

The receiving side of a synapse – the sensitive tip of the spike called a dendrite in the picture above – is the most molecularly complex structure in the body, built from

1100 different proteins. This tip has increased in complexity dramatically throughout evolution, indicating that the development of this fundamental crossroads has been vital in what has made us human.

On average, each of the 100 billion neurons in your head has about 1000 connections with other neurons, creating a huge network of about 100 trillion synapses. Like a computer network built from one hundred trillion transistors, each representing a "bit" of information depending on whether it is "on" or "off."

Adding up all possible combinations of 100 billion neurons firing or not, the number of potential states of that neuronal network is approximately 10 to the millionth power: one followed by a million zeros.

With all that connectivity, circular loops are routine in which – to simplify – the A neuron triggers B which lights up C which signals D which triggers A. This circularity allows and fosters:

- The recursive processes needed for self-regulation - and which, after many layers and lots of evolution -- allow you to think about your own thinking

- The dynamic and "chaotic" behavior of complex systems: it's not random in your brain, but it is inherently *unpredictable.*

- Wandering stream of consciousness – Again to simplify: the C neuron in the circuit just mentioned could easily be part of another circuit having nothing to do with the first one. Nonetheless, because of that connection, when the first circuit fires the second is more likely to fire as well. That's why thinking about something like a dripping faucet can bring to mind something seemingly random like your grandmother's great oatmeal cookies.

In sum, your brain is literally the most complex object known in the universe. More complex than the climate of our planet or an exploding star.

Speed

Neurons typically fire 5 – 50 times a second, with millions and even billions of them pulsing in harmony with each other many times a second; the electrical currents of that pulsing are revealed as brain waves in an EEG.

In the half second it takes you to clap your hands, billions of synapses have activated in your brain.

Most brain activity is lightning fast and forever outside of awareness. The slower, more congealed turgid stuff that we call thought is just the observable tip of an iceberg of lightning quick electrical, chemical - and possibly quantum - activities.

Activity

In the deepest sleep, and even in such a deep coma that artificial life support is needed, the brain is always humming away, always "on," with billions of neurons firing every minute, in order to keep your body alive and ready for immediate survival activities.

Consequently, your brain – about 2% of the weight of a typical person - consumes about 20% of the oxygen and glucose circulating in your blood.

Evolution

Your brain is the product of 3.5 billion years of intense evolutionary pressure, including 2.7 million years as tool-using hominids and over 100,000 years as *homo sapiens.*

Human DNA is about 98-99% identical to chimpanzee DNA. But that crucial 1-2% difference is mainly the genetic factors affecting the brain – especially for its relationship functions. In fact, the latest science suggests that the evolution of the brain was driven in two steps having to do with the survival benefits of strong relationships.

First, among vertebrates, many bird and mammal species developed pair bonding as a way to raise children who survived. (Remember that fish and reptiles generally do not raise their young and may in fact eat them if they happen upon them soon after they hatch.)

The "computational requirements" of choosing a good mate, working things out together, and then raising young to survive – hey, it's just sparrow and squirrel couples, but anyone who has raised kids knows what I'm talking about – required larger brains than those of reptiles or fish that dealt with similar environmental challenges but made their way in life on their own.

By the way, it may be a source of satisfaction to some that polygamous species usually have the smallest brains.

Second, building on this initial jump in brain size, among primate species, the larger the social group, the bigger the brain. (And the key word here is <u>social</u>, since group size alone doesn't create a big brain; if it did, cattle would be geniuses.)

In other words, the "computational requirements" of dealing with lots of individuals – the alliances, the adversaries, all the politics! – in a baboon or ape troupe pushed the evolution of the brain.

In sum: More than learning how to use tools, more than being successful at violence, more than adapting to moving out of the forest into the grasslands of Africa, it was learning how to love and live with each other that drove human evolution!

Mind

What is the reason for the remarkable complexity, speed, activity, and evolution of the brain? It is the *mind*.

By "mind," we mean the flows of information within the brain; a synonymous term is "mental activity." Much as the function of the heart is to move blood around, the function of the brain is to move information around.

The standard view among psychologists and neurologists is that most – if not all – subjective, immaterial states of mind have a one-to-one correspondence with underlying objective, material states of brain. (The distinction between "most" and "all" refers to the possibility of transcendental factors outside the realm of conventional scientific models of the universe.)

Within this standard framework, *the mind **is** what the brain **does**.*

In effect, the mind consists of the representations of the brain about the state of the world, the state of the organism's body, and the state of the organism's mind (which would be representations of representations).

Just like the menu is not the meal, and the map is not the land itself, those representations are not reality itself. They may be pretty good approximations, but they are not ever complete and entirely true. For example, consider going for a walk with a dog: the dog hears ultrasonic noises and smells things that you do not, but you see in color (presumably) while the dog does not. Physical reality is the same for both of you, but your perception and thus your experience of it will be somewhat different.

This point may seem merely intellectual or even confusing at first, but it is important to absorb its cautionary and humbling implications. The brain constructs views about the world, and about the state of your body and your mind, but those views are also one of the four objects of attachment noted by the Buddha as sources of suffering.

Even with the healthiest brain in the world, we need to hold those views lightly, as provisional, best-guess, probably-at-least-partly-wrong, and always incomplete formulations about reality.

And for someone with a wounded brain, this caution is especially important. Head injuries, strokes, ADHD, depression, and so on all tend to predispose people to be particularly selective or distortive in what they notice about reality. In such cases, it is really beneficial to be aware of these tendencies, put in correction factors (like double-checking), and rely on trustworthy others for reality checks.

Integration of Mind and Brain

This linking of mind and brain has three important implications.

First, as your mind changes, your brain changes. Your brain changes both temporarily, millisecond by millisecond, *AND* it changes in lasting ways because – in the famous saying of the Canadian psychologist, Donald Hebb – "neurons that fire together, *wire* together."

The fleeting flow of experience leaves behind lasting marks on your brain, much like a spring shower leaves little tracks on a hillside.

For example, the fine motor areas of pianists are measurably thicker than those of non-pianists. Similarly, the portions of the hippocampus that are responsible for spatial memory are discernibly thicker in experienced London taxi drivers compared to when they started their training. On a darker note, chronic serious trauma and stress lead to a noticeably smaller hippocampus, which also has a central role in registering new experiences into memory.

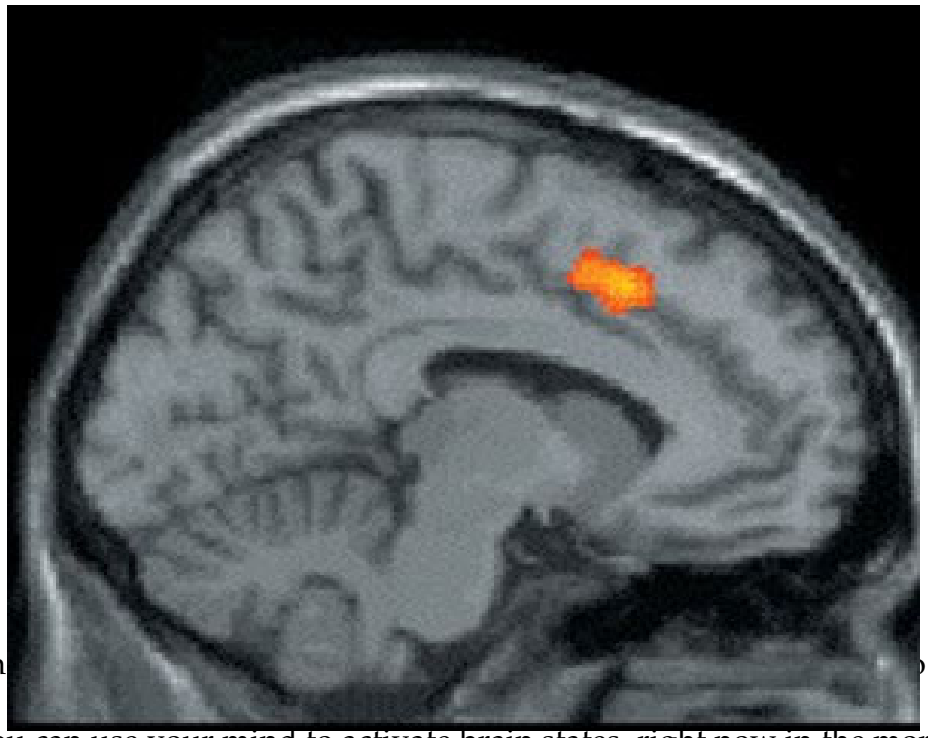
Second, as your brain changes, your mind changes. For example, if millions of your neurons start firing together in relatively slow rhythms – called Alpha waves – you will experience a growing sense of peacefulness and calm. Alternately, if your hypothalamus tells your pituitary to tell your adrenal glands to release epinephrine, cortisol, and other stress hormones, you will feel revved up to fight or flee.

Third, you can use your mind to change your brain to benefit yourself – and everyone else whose life you touch.

It may seem a little disorienting at first to think about "using your mind to change your brain to change your mind," to intervene within your own brain at the organic, material level. But it's actually very natural. For an everyday example, consider how

you might routinely change your brain with a cup of coffee or tea – or a donut! – to feel more focused in an afternoon meeting.

And for a more profound example, the image just below shows a part of the brain that is very active during deep meditation or prayer – when the rest of the brain is relatively quiet, and thus shown in gray and not "lit up" in orange. The area in orange in the slide is called the **anterior** (frontal) **cingulate gyrus,** or ACC, which plays a central role in controlling attention. With routine meditation, the ACC and some other regions become measurably thicker.



You can ways.

First, you can use your mind to activate brain states, right now in the moment, that promote patience or inner peace or other positive qualities in response to difficulties, such as wounds to your brain.

Second, since "neurons that fire together, wire together," by deliberately cultivating wholesome states of mind, over time you create permanent, structural changes in your brain. Those changes may be a matter of uncovering a Buddha Nature, or Transcendental Awareness, or True Self that was there all along – but the "removal of the obscurations" is still a change within a person's brain.

These scientific findings in modern psychology and neurology offer incredibly good news. They confirm the ancient teachings of the Buddha about the possibility of each person transforming his or her life – even to the point of enlightenment. They

nourish conviction, sometimes called faith: one of the seven factors of enlightenment. They explain why it is really beneficial to do certain practices, which encourages right effort. And they suggest new practices that may increase the power and penetration of traditional ones.

Mind Does Not Reduce to Brain

Nevertheless, with all the potential benefits of a scientific understanding of the brain, it is very important to remember that the mind does not reduce to the brain – even without reference to possible transcendental factors, and definitely if you presume such factors, as we do.

Within a purely Western, scientific framework, it is clear that the mind is in some ways causally independent of the brain:

- To be unavoidably technical: mind is patterns of information represented by patterns of matter. Since much mental information can be represented by any suitable neural circuit – much like a picture can be represented by any available RAM on your computer – it is functionally independent of its physical substrate.

- This independence enables thoughts (and other aspects of mind) to be the fundamental cause of other thoughts; the brain carries thoughts but it does not necessarily *cause* them.

- Mind can cause changes in matter (the material brain) through its embedding in the matter that represents it; for example, immaterial thoughts of gratitude are embodied in cascading physical processes which can trigger <u>physical</u> circuits that dampen the release of stress hormones.

Lifelong Learning

Humans have the longest childhood of any animal on the planet – a remarkable fact. Since children are very vulnerable in the wild, why would evolution risk such a long childhood?

The reason is that there has been a big payoff - a net adaptive advantage - in giving the brain time, during childhood, to learn a vast number of things, and to become *trained* to be capable of the additional learning during adulthood that enables a person to adapt to and thrive in his or her environments.

All this learning means that the actual structure of the brain must change over time, in a dynamic unfolding process enabled by mechanisms like these:

- Neuronal pruning from the moment of birth: a kind of natural selection within your own brain in which inactive neurons die (“use it or lose it”)

- Greater excitability of individual neurons due to increases in their activity
- Increased blood flow to active neuronal regions
- Stronger synapses between neurons that are firing
- New synapses – "arborization" – among active neurons, like eager spring growth of twigs and buds stretching toward each other in the great forest of the brain

Interestingly, the part of the brain that takes the longest time to fully develop is the prefrontal cortex, which is centrally involved in the "executive functions" of planning and the regulation of feelings and actions.

Stability and Instability

The brain is continually moving back and forth between stable states followed by disturbance and then reorganization into a new stability. In a sense, stability constitutes a signal (in that it is unlikely, in terms of information theory), while instability is a backdrop of "noise" – though very fertile noise, indeed.

These rhythms of stability and instability occur both over long time scales – such as the years of adolescence – and very quickly, such as dozens, perhaps even hundreds of times a second. Stability is needed to have any kind of place to operate from in the world, and instability is needed to have any kind of learning or adaptation.

Within your brain, large numbers of *ad hoc* neural assemblies – whose individual neuronal members keep changing – are continually pulsing. Each pulse is a momentarily stable waveform which rapidly decays and disintegrates – an illustration of impermanence, one of the three fundamental characteristics of existence identified by the Buddha.

Then there is a kind of fertile instability, an instant of spacious neurological possibility, out of which the next pulse of stable order comes. That spaciousness is a kind of emptiness akin to the absolute nature posited in Tibetan Buddhism within which the universe eternally flickers into and out of existence. In sum, because of the multiplicity and speed of neural assemblies, there are many, many pulses of functional emptiness every second in your brain.

Specialization and Teamwork

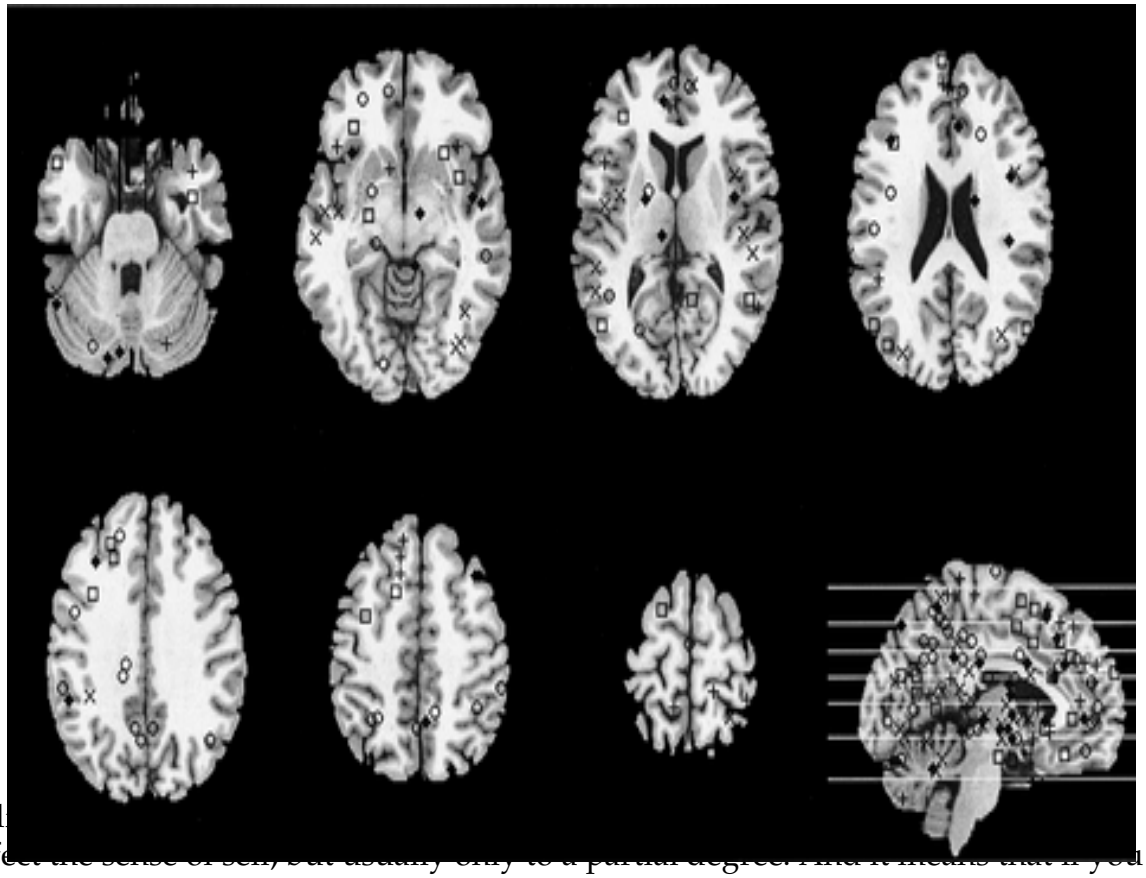
The brain works through an exquisite combination of specialization and teamwork. On the one hand, different parts of the brain do specialized things. For example, one

part handles *producing* meaningful speech while another part is in charge of *comprehending* it. Similarly, there's a dedicated system for processing faces.

But on the other hand, those various parts work intimately together. Connectivity is the hallmark of the brain, and interestingly, a *busy* network system is more responsive to individual messages getting through: Paradoxically, noise in a network fosters clear signals! As Robert Heinlein said, *"Specialization is for insects."*

This property of teamwork means that information such as memories is often widely distributed throughout the brain, not in one place. And under many conditions, one part can gradually take over the function of another if it's damaged, an example of what is called "neuroplasticity."

Further, the self itself is not localized to any single region of the brain. In the image just below (from Gillihan, et al., *Psychological Bulletin,* January, 2005), each one of the little squares, plusses, and crosses represents a different part of the brain activating during different self-oriented activities (e.g., recognizing oneself in a picture, deciding what one wants).



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quiet the sense of self through not identifying with things or taking them so personally, you tend to quiet the brain overall – which is useful during meditation and other similar activities.

Individuality

Each brain is unique, for many reasons.

First, there is genetically-based variation in the quantity and sensitivity of receptors in the brain for dopamine, serotonin, norepinephrine, and probably other important neurotransmitters.

Second, new research is revealing subtle but important differences in certain aspects of male and female brains.

Third, the synaptic connections that correspond to something as simple as the number one differ in a thousand tiny ways in the brains of different people.

Fourth, whatever our genetic endowment might have been, events *in utero* and from the moment of birth to this present instant have all influenced your brain.

All this calls for respect for individual differences. And for compassion for ourselves and others.

As it is traditionally said, there are four types of practitioners: those for whom practice is easy and quick, for whom practice is hard and quick, for whom practice is easy and long, and for whom practice is hard and long. Whichever group you belong to, what matters most is to practice wherever you are and feed the causes that will lead you to a good result.

And one of the most effective, most fruitful causes to support is the care and feeding of your own brain!

Natural State of Your Brain

When you are fed, unthreatened, pain-free, and not upset, your brain is characterized by being awake and alert, with activation of the parasympathetic nervous system (discussed a few minutes ago), surges of pleasant hormones and neurotransmitters, receptivity to relationship, and a large-scale integration or coherence of billions of neurons firing together in resonant harmony.

In short, the baseline condition of your brain is aware, even-keeled, contented, benign, and integrated.

It's remarkable that this is the resting state of an organ that's been finely honed by 650 million years of evolution of multi-celled creatures in an environment in which life typically was, as Hobbes put it, "nasty, brutish, and short."

This is your home base. It may have been disturbed by an injury or a chemical imbalance or a degenerative conditions. But wherever you go – deep, deep down where your essential nature arises, you are always already home. As J.R.R. Tolkein wrote just below, no matter how dark it gets, there is always light shining through:

Exhausted, crawling with Frodo up the slopes of Mount Doom in the center of the gloom of Mordor, Sam sees *"peeping among the cloud-wrack . . . a white star twinkle for a while. The beauty of it smote his heart, as he looked up out of the forsaken land, and hope returned to him. For like a shaft, clear and cold, the thought pierced him that in the end the Shadow was only a small and passing thing: there was light and high beauty for ever beyond its reach."*

Or, to quote Ajahn Sumedho:

> *Be wisdom itself,*
> *rather than a person who isn't wise*
> *trying to become wise.*
>
> *Trust in awareness, in being awake,*
> *rather than in transient and unstable conditions.*