Talk #7 An Organ that Minds

> So let us stand back and imagine our brain with its hundreds of trillions of synaptic connections. Each synapse is potentially a unique computational unit with its own molecular tool kit, history, memory and function. The neurons and their synapses are in a constant state of flux – the connections are dynamic, changing their size, strength and location; being formed and unformed. Every second, millions of electrical impulses course along the fine fibrous extensions of the neurons, carrying electrical and chemical messages through a gelatinous interconnected circuitry that is more complex by far than that of any computer. . . . There are as many as 100 glial cells for each nerve cell and we are only beginning to understand just how important they are, not simply carrying out housekeeping jobs but participating in the brain's computations regulating synaptic transmission, among other ways.
>
> This then – the neurons and their connections and their history, their companion glial cells, the multitude of chemical messengers and receptors – is basically all there is to the brain. We are far from understanding how it works as a whole but there is nothing more, no magic, no additional components to account for every thought, each perception and emotion, all our memories, our personality, fears, loves and curiosities.
>
> – The Brain: A Very Short Introduction,
> Michael O'Shea (2005)

Thea: Tonight, you were going to tell me about the brain.

Guy: I'll tell you what I can about it. It's the most complicated system in the known universe; and one great thing we've learned about the brain is how much we still don't know. But there is reason to think we are at last on the right track: that we are asking the right questions, after all these years.

Thea: Many old ideas about it have been shot down. Why do you think the present ones will fare better?

Guy: Previous ideas were based on crude analogies with water pipes, steam engines, digital computers; and were mostly pure speculation. Those of today are based on a very considerable knowledge of the brain's physiology and cognitive anatomy (which mental functions are performed where). We have a solid grip on the functioning of neurons and other brain cells, and on the physics and chemistry of neural interaction. And, as I've already shown you, we are beginning to see how mind-like capabilities could emerge in the ultra-complex activities of components which themselves have only rudimentary minds, if any at all. Though there are still many pieces missing, the ones in place now are probably more or less correct.

Thea: You're sure of this?

Guy: I claim no certainties at all. It is not the way of science to do so. By now, though, there is a large body of precise information on the brain's workings, and the areas of controversy are pretty narrow. Barring radical discoveries that force a further change of paradigm, our understanding of the brain looks pretty solid at this point. And even in the event of such discoveries, the new ideas would necessarily be built on the debris of present ones, and would have to take old data into account. Across the board, that is what science delivers:

Theory may change, but understanding deepens and advances, precisely because some minds (too few, unfortunately!) have learned to live without specious certainties.

Thea: I'll grant that we know a great deal about the brain by now, and quite a lot about the mind as well. But what do we actually know of the relationship between them? To begin with, why do we think there is a relationship? That a mind is what a brain is doing, as you like to say?

brain science

Guy: Actually, the relationship of mind to brain is by no means obvious. The ancient Egyptians didn't see it. For all their knowledge of human anatomy, their embalmers prepared clients' livers and hearts with great care, but removed their brains entirely, packing the skull with cloth. It would seem that they attached no great importance to that organ, and saw no use for it in the afterlife. By about 500 BCE, however, a Greek named Alcmaeon dissected the optic nerve leading to the brain, and inferred its role as a center of perception. Around 350, Hippocrates, presumably on the same evidence, stated that the brain was involved with sensation and intelligence. He probably imagined the nerves as little pipes, carrying sensations from the eyes and ears to a central site of consciousness.

Thea: OK. That seems reasonable. But just because sensory messages are carried to a central location doesn't tell you anything at all about the way they are handled there: how the world is experienced, how choices are made, how concrete intentions are formed and carried out.

Guy: True. We're only now becoming able to address those questions in any serious way. In one form or other, a doctrine of the mind as "soul" or "vital spirit" prevailed for nearly 2000 years. It still lingers in common speech and consciousness, and is still useful in certain fields like acupuncture, yoga, and martial arts.[1] Of course, "vital spirit" does not explain life and mind any more than the word "gravity" explains gravity. But the concept made, and still makes a convenient file drawer for ignorance – a convenient way of thinking when real explanation isn't needed.

It was only in the late 18th century, that the electrical character of nerve impulses was discovered when Luigi Galvani found that he could make a frog's leg twitch by stimulating the nerve with an electric current. With refined technique it was shown a little later that the same effect could be produced by stimulating an individual nerve fibre – even a single neuron as one of the long cells found both in nerve fibres and brains came to be called.

By 1870 Camillo Golgi had developed a staining technique that permitted microscopic imaging of the anatomy of the individual nervous cell, and had established that neurons in the brain received information through neurons coming to the brain from sense organs, and in turn sent information through neurons to the muscles. He went on to propose that the nervous system was an elaborate network of such neurons, with electric charges flowing continuously from one neuron to the next. A few years later, however, a Spanish neurologist named Ram¢n y Cajal showed that neurons did not

---

1 Notably, in aikido and tai chi.

comprise a continuous network but were both separated and linked, each to the next, by a minute gap that Charles Sherrington called a synapse. By the last decade of the 19th century, Ram¢n y Cajal and others were already speculating that learning and memory were emergent features of the brain's plasticity – specifically, of the change and growth in the pathways of neuron and synapse. However, some neurologists refused to accept this synapse theory and clung to Golgi's reticular theory of the brain as a continuous net.

Thea: But this controversy has since been settled, hasn't it? Chemical neuro-transmitters that carry nerve impulses across the synapse are getting a lot of attention these days.

Guy: Indeed they are; but the brain's fine structure is far from settled. Ram¢n y Cajal was mostly right, but recently certain regions have been found with the reticular structure that Golgi posited. In the early years of the 20th century, it was discovered that a chemical substance called "adrenaline" could help an electrical pulse cross the synapse from one neuron to another. By mid century, another neurotransmitter – noradrenaline – had been discovered, and by now some 41 different substances are known to carry, or modulate the carrying of electrical impulses across the synapse from one neuron to another.[2] As well, there are those so-called "glial cells"[3] outnumbering neurons by a factor of about 10 to 1, which turn out to be much more important than was previously thought. All-in-all, the more we learn about the brain, the more complicated it appears.

Thea: Aren't you contradicting yourself a little here? A short while ago, you said our current understanding of the brain was probably more or less correct.

Guy: No contradiction. I said there was reason to believe we're on the right track about the brain/mind system – not that all questions have been answered. Learning that we had underestimated those glia actually increases our confidence more than not. Prior to these new findings, it seemed strange that so many glial cells were doing so little. At last, their role is becoming clear – and in a way that confirms and enriches the picture we'd had before.

We've gotten ahead of ourselves a bit. The take-away point from this talk so far is that by the end of the 19th century, both neurophysiology and psychology/psychiatry were both well-established branches of investigation; and it had become clear to the leaders in each – to psychologists like Charcot, Breuer, Freud and William James, and also to neuro-anatomists and physiologists like Wilhelm Wundt, Hughlings Jackson, Camillo Golgi, Ram¢n y Cajal and Sherrington – that they were studying the same system from different points of view.

Thea: What brought them to that conclusion? You still haven't told me what made them think so.

---

2 A table of these substances can be found at *http://en.wikipedia.org/wiki/Neurotransmitter#Common_neurotransmitters*

3 The name comes from the Greek word for "glue."

Guy: Just the accumulating evidence that physical events and conditions could influence mental ones and vice versa; a growing awareness that mind and body were thoroughly inter-linked. On the physical side, they knew about reflex arcs producing unintended movements of the body. They knew that diet and drugs and fatigue and pain could produce emotional and attitudinal changes. They knew about the cognitive and emotional results of various types of brain injury. On the mental side they knew that hypnotic suggestion could produce astonishing physical effects. They knew about placebos: how a sugar pill could alleviate pain and bring about inexplicable cures because the patient believed in the medicine. They knew of certain puzzling ailments with no discernible cause that produced impaired cognition, weird physiological effects and great emotional suffering. What other conclusion could they draw?

The problem then became to understand the relationship between these twin perspectives: how the mind is produced through the body's functioning, and how mental events like memories, emotions and volition itself could affect the body's functions.

Thea: I'm glad you added that last bit: Science-minded types sometimes talk as if they'd forgotten that the conscious and unconscious mind can influence the body.

Guy: Indeed, there is that risk when the mind's dependence on the brain is taken seriously. Yet we now understand clearly that the arrows of influence are circular in the brain, as in any eco-system. The whole is made up of its component parts, but in turn strongly influences its parts by setting the context in which they work. Society too, and what we call "culture," and the natural world itself, set an even larger context for the firing patterns of the individual's brain. So, to be accurate, we have to ask neither how brains produce minds, nor how minds direct their brains, but rather how brain/mind systems evolve and stabilize and change in the entire holarchic context.

Thea: But you – people like you – always talk as if the brain explained everything.

Guy: It's true that we hope eventually to understand the connection between mental events and neural ones in detail, down at the neural level and synaptic level; and yes: we reject "skyhook" explanations – appeals to "Intelligent Design" and the super-natural – and think of mind as a collective consequence or outcome of the activities of people's brains. But we are not behaviorists. We freely grant that ideas and desires and feelings are legitimate objects of discourse and study, and have to keep reminding ideologues of all stripes that causation in the brain goes in re-entrant loops. We know very well that cognitive content and context (global effects at the social and organismic levels) can influence specific physiological processes in much the same way that our understanding of the meaning of a text affects the meanings we assign to its ambiguous words. There really is no genuine argument here. The quarrel exists only among the simple-minded on both sides.

Thea: All right. I surely don't want to be counted among the simple minded. But I've pulled you ahead of your story again. You haven't told me how the neurons work, and how the neural electricity is produced and used.

Guy: For that discovery, two English physiologists, Hodgkin and Huxley, shared a Nobel prize in 1963. In effect, each neuron acts as a tiny battery, building up a small voltage – a difference in electrical charge – between the outside and inside of the cell.[4] When the neuron fires this difference breaks down, and an electrical pulse propagates along the length of the cell – out to the synapses where the cell comes almost in contact with others. What happens at the synapse, I've already described. Various neurotransmitter molecules carry suggestions across the gap to receptors on the other side – suggestions to the receiving cell to fire or wait.

Thea: So a neuron discharges when suggestions to fire outweigh the suggestions not to?

Guy: Actually, neurons fire fairly spontaneously from time to time, just to let off their accumulating charge. But the suggestions they receive across the synapses influence how often they fire: their firing frequencies. As Francis Crick put it, what one neuron tells another is just how much it is excited.[5] Which, in turn, is taken by that next neuron as a suggestion to get more or less excited. We know that a single neuron may be influenced by suggestions from a thousand or more other neurons – by the neurotransmitters crossing all those synaptic gaps. But even deprived of such in-fluences, an isolated neuron still discharges from time to time, and then regenerates a potential difference by pumping sodium ions out of the cell in exchange for potassium ions taken in.

In effect, then, the neurons can be thought of as suggers with their own, simple repertoires of behavior – firing when they feel like it, and emitting various neurotransmitters in doing so. Their readiness, however, is influenced by suggestions from other neurons – passed either through those neurotransmitter molecules or by direct electrical contact. And their firing may also be taken as suggestions by other specialized cells – by muscle cells to contract, or by gland cells to release digestive juices or hormones. And this activity, in turn, feeds back as suggestions influencing the central neurons. In this way, the whole system resonates – falls into rhythms of neural firing and bodily activity – in sync with itself and with the world around it.

Thea: So the brain as a whole works like those nerve nets you were telling me about?

Guy: Put it the other way: Those artificial nerve nets were designed[6] back in the 1950's to model the brain as it was then beginning to be understood[7]. That early model needs updating now to fit what is known today.

Thea: Updating how?

Guy: Let's put that question aside for the moment. Before we talk further about the

---

4 See, for example, *www.enchantedlearning.com/subjects/anatomy/brain/Neuron.shtml*

5 See discussion of the patterns of neural firing at *http://www.cwa.mdx.ac.uk/chris/talks/maastric/CANT.html.*

6 By Frank Rosenblatt.

7 By neuro-scientists like Warren McCulloch, Walter Pitts and Donald Hebb.

brain as a neural network, I'd like to introduce a different perspective – a functional one. We can strip away the physiological detail (about the firing of neurons, and neural networks), and think of the brain as comprised of numerous modules or sub-systems, linked together and collaborating somehow. Each module performs its specialized function, and each communicates somehow with other modules. The functionality of the whole brain will then be seen as emerging from the specific functionality of its parts in much the same way that a computer program calls its subroutines.

Thea: Parts made up of hundreds or thousands of neurons, connecting one to another in a way allowing some coherent functionality for this assembly within the system as a whole. Is that what you are saying?.

functions and agencies

Guy: Yes. The neural network as a whole is too complicated to understand in its entirety. But we can simplify it, at least conceptually, in the same way that programmers design a complex system by isolating its high-level functions and progressively decomposing these into more specialized functions. Like those holons we were discussing the other evening. What we get, hopefully, is a hierarchical block diagram of functional modules that an engineer might try to build, or that a programmer might try to emulate on a fast computer.

Think of it this way: Mind/brain research is proceeding on at least three fronts: For some time now, philosophers and psychologists have been working out the functionalities of mind from an external top-down perspective. Neuro-anatomists and neuro-psychologists have sought to locate recognized functions of mind in specific structures and neural circuits that we can trace and diagram. Since the 1950's, engineers engaged in artificial intelligence (AI) research have been attempting to simulate aspects of a brain's functionality on their computers, and with artificial neural networks. When and if these lines converge, we can regard the brain puzzle as solved.

Thea: I don't have to ask you how this three-pronged project is coming along. I know you think it's doing very well.

Guy: It is doing well – although, as I keep saying, there's still plenty of work to do. But today we can give a functional account of the brain down to levels at which a physiological implementation is plausible – and, in some cases, actually duplicable with engineered components.

Thea: What you're saying then is that we can think of the mind as software of a kind, that runs on the brain the way a program runs on a computer. We can think of our minds as calling specialized functions as it needs them – the way a computer program calls its modules and sub-routines.

Guy: That approach has been explored by the Artificial Intelligence people, and probably taken about as far as it can go. Forget conventional computer software that executes one instruction at a time. Real brains seem to work more in the way that Marvin Minsky described, in a famous book called The Society of Mind. His idea was that the mind/brain can be thought of as an association of semi-autonomous agencies, comprised of mindless agents that perform their specialized tasks in parallel, with little regard for what the others are doing. These agents are not logically coordinated like the modules and sub-routines of a computer program. Each just "does its thing," competing for influence within the system as a whole. Like a kind of ecology, in fact – as Gregory Bateson had suggested.[8]

Thea: Was Minsky influenced by Bateson?

Guy: Not that I know of. He may have been. But Minsky was coming at the problem as an AI researcher, not a biologist. He actually proposed a number of mechanisms – programmable mechanisms – by which the mind's agencies could work together – through which the competitions amongst them could be resolved.

Thea: Before you explain how the agencies of mind could work together, don't you need to describe how they are built?

Guy: No, not really. For a purely functional description, we don't care how the modules are built – how their functions are actually performed. Instead, we can take what engineers call a "black box approach," thinking of each module as performed by a component whose relationship to other components is specified, but whose internal workings remain unknown.

The thing about a black box is that we don't need to worry how it is implemented. It might be a computer program, pieced together from modules and sub-routines. It might be a dance of angels on a pin. Eventually, of course, we hope to understand the mind's agencies and agents as neural circuits.

Thea: So then, it will turn out that Minsky's agencies are implemented in the brain as chains and loops of neurons that pass suggestions to one another, getting each other more or less excited.

Guy: And settling down into more or less stable rhythmic patterns that propagate through the brain, recruiting the collaboration of other agencies as needed, but competing with one another to do so.

Thea: Seeking a loose stability, analogous to the eco-systems of living organisms – and never really controlled, but only influenced.

Guy: You've got it. Minsky conceived his agencies in computational terms, but they might be better understood as suggestion processors, each with its repertoire of responsiveness and activity, competing for resources across the brain as a whole.

Thea: You know, I can see the beauty in all this work. But what you've shown me so far is just an organ that converts stimuli into activity, input into output. But it doesn't feel pleasure or pain yet, much less beauty or reverence. It doesn't have beliefs or desires or intentions. It may have skills – perhaps very complex ones – but it has no memories or plans or hopes. You're still a long way from

---

8 In Minsky's words, "The power of intelligence stems from our vast diversity, not from any single, perfect principle. . . . they emerge from conflicts and negotiations among societies of processes that constantly challenge one another." The Society of Mind, Chapter 30.8.

showing that such a network is capable of consciousness.

By now, I don't doubt that the brain works much as you describe, and that it can weave something like a mind in doing so. But your reduction of mind to neurophysiology still seems like a confusion of categories. Mind and brain, as you've acknowledged yourself, are two different languages. The burden is still on you: How do you find mind in the workings of a brain?

traces of thought

Guy: I can make a start at an answer to that question, but little more because the brain/mind connection, what we know of it, is fearfully complicated. The research is very difficult, because the patterns we seek are temporal ones, and because in living brains, many events are happening simultaneously. As well, the neurons implicated in some particular mental event are threaded around the brain, not found at one or a few locations that could be studied easily.

But progress is happening. We know in some detail, now, how light falling on the retinas of your eyes is converted into neural firing rhythms which are then associated with each other, with other sensory data, and with neural patterns corresponding to relevant memories and concepts, to assemble a mental picture of the world around you. We know, quite accurately where different parts of your body are represented in your brain. On the output side, we are beginning to understand how motor activity is assembled and coordinated to produce complex, highly skilled movement.

Thea: What about learning? What about memory? What about motivation and emotion?

Guy: One thing at a time. Emotion is a hot area of research just now, partly because its significance was not understood until quite recently, and partly because the crucial distinction between affect and emotion was not understood.

Thea: You know, I've never been clear on that distinction. Most therapists use the terms interchangeably. Can you explain the difference between affect and emotion,[9] and why it's so important?

Guy: The distinction is a simple one: Affect is a matter of physiology; emotion is learned – and is already a form of cognition. Every healthy infant comes equipped with a functioning affect system, signaling distress, contentment, interest and so forth with stereotyped physiological program that are the same everywhere. For genetic and ontogenetic reasons linked to foetal development, the affect triggers may vary in sensitivity from one individual to another – those variances comprising a large part of what we call temperament.

Affect tends to be involuntary. It is highly communicable, and tends to be contagious, especially in social animals like ourselves.

Thea: And the emotions are built upon those physiological affects?

Guy: Right. By the time the infant is a few months old, the affects are already

---

9 See Donald Nathanson's *Shame and Pride: Affect, Sex and the Birth of the Self* or my precis of that book, *Affect Theory, Shame and the Logic of Personality* on my web site at *www.secthoughts.com*.

grouping together and becoming linked with familiar situations. These associative clusters are not innate and automatic. Already, they are individually constructed responses to recog-nized groupings of stimulation.

Where affect is a kind of program hard-wired into the nervous system, emotion represents an elaboration and interpretation of one or more affects in a perceived situation. Emotion is cognitive, and will come to involve the categories and concepts of a life-history and a culture.

Thea: What affects are there?

Guy: Nathanson identifies nine of them – in addition to pleasure and pain which, for technical reasons, are assigned to a separate system of their own. Their names are interest-excitement, enjoyment-joy, surprise-startle, distress-anguish, anger-rage, fear-terror, dissmell, disgust and shame-humiliation. The compound, hyphenated names were intended to distinguish these raw affects from the emotions they underlie, and to which they give rise. There's no agreement yet on just how many and which affects there are, though the affects of fear and anger have been widely studied. But for our purpose, a definitive catalog of human affects is less important than the concept itself.

Thea: Then what we call desires or motivations are built on pleasure/pain and the emotions?

Guy: The crucial point here is that beliefs, desires, intentions and bodily actions are outputs of specific sub-systems – "agencies" in Minsky's language. There is no reason at all, why these outputs need be consistent or even mutually intelligible to one another.

Thea: So there really is no mystery about the conflicts between "heart" and "head" – reason and emotion?

Guy: The brain's competing agencies explain such conflicts very nicely. It's not only possible but completely normal for us to want things that are mutually incompatible, and to believe inconsistent ideas. That's just the way the system works.

Thea: To the point that wholly different "personalities" can develop around such complexes of emotion and attitude. It's not even pathological, until the rival complexes lose touch with one another, as they do in multiple personality disorder (MPSD).

Guy: Right. MPSD is not caused by demonic possession. It's not even terribly mysterious, once you accept the fundamental autonomy of a brain's agencies, and their on-going competition for dominance in this or that situation. Likewise with "Freudian slips," psychosomatic symptoms, non-accidental accidents, and other cases in which a mind appears to work against itself. The ecoDarwinian paradigm explains such errors and conflicts very nicely.

learning

Thea: What can you say about learning? I remember that in a previous talk[10] you said a little about Darwinian trial-and-error learning in artificial nerve nets, but you haven't said anything at all yet about learning in real brains. Does human learning work that same way?

Guy: In general the answer is "yes," though there is still debate on the subject. But the general picture is clear enough. A brain in its body evolves toward attunement with its environment. And with itself, of course. What we call "learning" is this evolution.

Thea: Well, it would have to work in some such way, wouldn't it? By getting rid of behaviors that don't work and experimenting further with those that do. The behaviorists called the process "reinforcement." But they said nothing about the physiology of learning at the neural level. So far, neither have you.

Guy: There's not much more I could say now. The human brain is very good at some learning tasks and not so good at others, and we are still a long way from understanding the protocols it uses or their physiological implementation.

Check out the Wikipedia articles on real and artificial neural nets.[11] You won't find them easy reading, but you'll get a sense of where we are now – the current state of neurophysiology and neural net engineering.

Thea: One objection: It's true that some human learning appears to happen gradually – plausibly in the evolutionary fashion you are describing. But some learning occurs instantaneously. You meet someone briefly and then recognize her a week later. You walk around in a strange neighborhood and somehow, in doing so, build a mental map of it. A month later you can find the convenience store, or the post office, or that nice little restaurant with no trouble at all. You have a flash of insight like Archimedes in his bathtub, and suddenly know how to solve a problem that's been bugging you for weeks. These cases sound like something more than the random building and tuning of neural connections.

Guy: You've just raised what is probably the strongest argument against "connectionism" – this model of the brain as a sophisticated nerve net. It just does not seem possible that all types of learning are achieved by a gradual formation and adjustment of synaptic connections. There must be more to it than that – or so many researchers feel.

Thea: And what would you say?

Guy: That it's an area of hot debate between specialists, where I'm scarcely entitled to an opinion. My guess is that both sides are right: At the lowest level, learning may be no more than a formation and tuning of synaptic connections, as the connec-tionists maintain. But that process is probably much faster and subtler, at least in certain areas, than has so far been established.

One thing that does seem clear now is that learning is not simply a generic

---

10 Talk #4.

11 At *http://en.wikipedia.org/wiki/Neural_network* and *http://en.wikipedia.org/wiki/Artificial_neural_network* respectively.

capability that works the same way across the board, regardless of content. On the contrary, the ability to learn is domain-specific: we learn some things much more easily and rapidly than others. There are things that we learn only with great difficulty. We may be unable even to notice that there's a pattern to be learned; we may not be able to hold a pattern's elements in working memory for long enough to make the connection between them. But, at the same time, there are things (like a native language) that we seem pre-disposed to learn – in physiological windows of opportunity, with remarkably sparse prompting. Other cases of rapid learning may well invoke and build upon the power of language to pre-structure new experience through previously learned categories and metaphors. We don't fully understand these processes yet; but they seem to modify the connectionist model in certain respects, while leaving its basic concepts intact.

Thea: All right. I'm ready to concede that a physiological perspective on the mind may indeed be valuable. I certainly agree that the folk psychology tends to see people as more coherent, conscious and rational than we really are. But Freud already knew that.

Guy: Freud started out as a neurologist if you recall. This physiological perspective would not have been strange to him. It confirms some of his greatest insights, and replaces some aspects of his mythology with hard science. He would have seen himself as one of its forerunners – as, indeed, he was.

folk psychology vs. neuro-psychology

Thea: This may be a silly question, or a naive one, but I'll ask it anyway: On the bottom line, what does the brain actually do? Is there any simple way to explain its function?

We've spent hours talking about brain science, but if a child asked me what the brain is for, I still wouldn't know how to answer; and all the information you've given me would go right over her head – as much of it, frankly, goes over mine. So, if the question makes sense, answer it as you might answer a bright 10-year-old: In the physiology of a living organism, what precise function did the brain evolve to serve?

Guy: Actually, I think you're asking a very good question. It isn't silly at all. You could tell this kid that the stomach digests, that the heart pumps blood, that the kidneys filter waste products. You could tell her that the lungs take in air, and supply the blood with oxygen; but a brief explanation of the brain, at that level of simplicity is not so easy. For example, we often say that we use our brains to think with, but actually we use them for much more than that. Conscious thinking, so far as we know, is limited to human brains – and remains the least part of what human brains do.

Reading in this area, I've asked your question myself. The best answer I come up with is that the brain creates and maintains a serviceable interface between the needs of an organism, and the opportunities and threats of its world. It tailors a creature's behavior to the environment in which it has to function. Fundamentally, it is as much an organ of survival as any other part of its body. Otherwise, it would not have evolved.[12]

The outstanding feature of a brain is its plasticity – and you can think about the Baldwin Effect in this connection. As the kidneys are specialized to filter the bloodstream, and the lungs to exchange carbon dioxide for oxygen, so the brain evolved to configure and re-configure itself to meet the challenges of a creature's environment. It needed a capability to change, to keep up with a world that is itself perpetually changing. And it had to become unique because, and to the extent that no two creatures, even of the same species, have identical personal worlds.

Thea: Would you say that is true of all brains, and all species? Can we tell our 10-year-old that the brain is an organ of interface and adaptation of the individual creature to its life-world?

Guy: I dare say, yes. That fits with what I know of my own brain and those of other people. It fits everything I have observed and read about the brains of animals. And it makes sense, because it accounts beautifully for the fact that frogs and fish and birds and cats – and above all humans – behave similarly as members of the same species, but differently (to varying degrees, of course) as individuals.

Thea: Accounts how?

Guy: It's obvious. If you see the brain as an organ of interface between the creature and its world, then perception and behavior must be similar for all the members of a species because each has similar sense organs and a similar body, facing similar problems of survival and reproduction. But, at the same time, each individual of a species must cope with a local habitat of its own: A fish swims in its own pond; a bird lays in its own nest; a tiger hunts on its own hill. Humans live in many different environments around the globe, and further tailor these to our own liking.

Each species evolves the brain it needs to accommodate a range of similarity and difference typical for its kind. And the brain of the individual creature then configures itself further, under the cognitive selection pressures of its daily experience, to lead its unique (but still more-or-less typical) life.

Thea: I see what you mean. Much of the fascination of my profession is the uniqueness, yet fundamental similarity of people's lives. We have different beliefs and somewhat different hopes and wishes – but always as variations on the same themes.

Guy: We tend to oscillate on this issue – between two poles, both of which are wrong. Either we see people as brothers and sisters under the skin, wanting the same consumer goods and driven by the same ultimate social and spiritual values. Or else we see them as driven by radically different cultural programs.

Our present understanding of the brain gives a much clearer idea of how people can be so different, and yet so fundamentally alike. We begin to see

---

12 "The brain is not an organ of thinking but an organ of survival, like claws and fangs. It is made in such a way as to make us accept as truth that which is only advantage." Albert Szent-Gyorgi

ourselves as evolving our brains and minds under the pressure of individual and cultural circumstance to be sure, but always from a starting point of biological humanity and temperament that is increasingly well understood – in professional literature at least, if not by the individual themselves.

Thea: Individual circumstances can vary very greatly, especially when you consider that two children, even of the same sex and within the same family, may grow up with very different parenting, saddled with very different family roles and expectations.

Guy: Leading to great differences in the way their brains get wired up.

Thea: And that is what boggles my mind: this claim that all our cultural and psychological differences ultimately reflect differences in the way our neurons are hooked together – differences in the configuration of all those synaptic connections. Or should I say it boggles my brain?

Guy: Why can't it boggle both?

growing a brain

Thea: It's a good story you're telling. I must admit that. But how do these wonderful brains get built? Their development inside the womb between conception and birth still seems miraculous.

Guy: Awe and wonder are fully appropriate responses, but no miracle is needed. Our brains get built in much the same way as other organs – through cell division, specialization and migration under the influence of proteins that individual cells secrete, as guided by their genes and by their local cellular and chemical environments. It's a complex process that we're just beginning to understand, but it's not a mystery any more.

Thea: Still, the brain must be orders of magnitude more complicated than any other organ, and its architecture – the connections it needs to function properly – must be correspondingly more precise. The coordination required for that development is inconceivable.

Guy: The neurons of a young brain migrate and wire themselves together in response to three levels of suggestion: from the genes, specifying which proteins can be produced, under what conditions; from an internal, electrochemical environment switching genes on and off, and thereby suggesting which proteins to produce now, in a given local situation; and from the environment of the whole organism, influencing the local environments of cells through the nourishment and stimulation they receive. Every young neuron groping for location and contacts in the developing brain is guided by these cues – and only by these, so far as we know.

The usual ecoDarwinian process of self-organization and ecological balancing also seems to be at work. We know that many more neurons are produced than actually survive in the newborn's brain, so there seems to be some kind of selection process going on – a form of programmed cell death known as apoptosis.[13]

The brain configured through this process acquires the architecture proper to its species, construing and acting upon its world in its typical way. At the same time, each brain adapts in a unique way, to match the idiosyncrasies of its unique, individual world – never exactly the same as for another individual. With brains as complex as ours, the scope for cultural patterning and personal idiosyncrasy is practically infinite.

Thea: When you describe it like that, it's hard to see how embryos get it right as often as they do – how they contrive to grow their brains with as few defects as actually occur.

Guy: You can see why embryology has become biology's key area. We begin to understand the genetic code; and we more or less under-stand the organism's gross physiology. But we don't know nearly enough yet about the connection between these levels: It scarcely seems possible that the fertilized egg could grow itself so reliably, with only its genes to guide it, into a complete, functioning organism. And yet that is what happens, almost every time.

---

13 See *http://en.wikipedia.org/wiki/Apoptosis.*