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Ten Essays by World Class School Students entitled:

What evidence do we have that teenagers' brains are different from adults' brains?

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What evidence do we have that teenagers' brains are different from adults' brains?

In this essay I will evaluate the differences between the teenage and adult brain. In the course of this, I will cover the physical changes of the brain and how this affects the teenager. The term "adolescence" is used to describe the process of changing from a child into an adult whereas a teenager is aged between thirteen and nineteen. These terms are both used in this essay to evaluate a similar period of development.

When considering the teenage brain, it is interesting to first look at the way its size develops from birth. Chudler records the growth; the new born baby's brain weighs just 350g-400g (with some variation between male, which is always bigger, and female). It grows the fastest in the first year of life, reaching 940g-970g. Its most noticeable period of growth is finished after the first three years when it has reached 1090g-1270g. The brain growth is now much slower until it reaches a peak of 1310g-1450g between the ages of nineteen and twenty-one. After this, is has been noted that the brain weight starts to decline and is on average 1200g-1400g in adulthood with a further decline as we age.

Blakemore and Choudhury (2006) describe the process of Magnetic Resonance Imaging (MRI); a MRI machine uses a large magnetic field to create detailed three-dimensional images of the brain without having to inject anything (unlike x-rays which require the injection of radioactive substances to show up soft tissue). This works as different parts of the brain have different magnetic properties (for example grey matter, white matter and blood vessels all appear differently). The scanner then records the signals that the magnetic field produces and this is then used to build an image of the brain. It is possible to look on the surface and deep into the brain.

Until recently, many scientists believed that the brain's growth was completed by the age of three (which corresponds with Chudler's research) and that the structure stayed the same apart from changes to the connections as children acquired more information when they went to school (Edmonds 2008). Recent research based on developments to MRI and other technologies have shown that this information is incorrect as the brain continues to develop well into the early twenties and different bodies of evidence will be evaluated here.

The most recent model of the brain is the plasticity model and is based on the fact that the brain can always be changed throughout life (Sentis, 2012). After the initial pruning, we use mostly the same neural pathways, shaped by our routine. This routine can be changed by consciously making an effort to do something differently and this affects the brain as it starts to divert away from the original pathway and starts to use a new one which, over time, becomes the usual one.

What changes in the structure of the brain?

The plasticity model of the brain plays a key part in the teenager's ability to learn. A SafeShare video reports a study into animals that were kept alone without social interaction and compared their brains to animals which were not alone. They found that the animals who did have social interaction had many more connections in their brain than those that did not. This can be linked to learning being important for teenagers' brain development. Vulliamy (2016) also comments that teenage years are when you are most receptive to learning.

Changes to the brain have been noted as starting from the back and working their way towards the front. The last part to change is the pre-frontal cortex, whereas the limbic system and in particular the nucleus accumbens (the part of the brain which responds to rewards) develops first (Blakemore, 2012, Edmonds, 2008). This is surprising as the pre-frontal cortex is considered to be one of the most important parts of the brain which is in charge of impulse control and planning. The implications of this will be explored later.

The changes start at a young age when the grey matter volume starts to increase, peaking at the age of eleven for girls and twelve for boys (Dvorsky, 2013, Giedd). Grey matter is made out of cell bodies and makes up a large proportion of the child brain. The grey matter levels start to decline after the peak as the brain starts to prune the synapses (Dvorsky 2013) leaving only the most used connections that the brain considers useful. After the unused connections are pruned away, the ones that are left become stronger and more effective at communicating and the myelination process begins (E.B 2015). The myelination process is when the neuronal axons (the long part of the cell that nerve signals travel along) are coated with white matter which is a fatty cell material. This is important as it speeds up signals and stops them from becoming diffused and not reaching the correct destination. This process replaces the grey matter with white matter and one of the last parts of the brain where this happens is the pre-frontal cortex that is reached in the early twenties (E.B. 2015).

By the age of six, the brain is ninety five percent of its adult size but the connections continue to develop and the grey matter continues to thicken throughout childhood. Giedd notes that this is similar to a tree continuing to develop its branches, twigs and roots.

What changes in the behaviour during the brain's development process?

The range of physical changes to the brain closely corresponds to the changes in behaviour and abilities of children and teenagers which start at an early stage. This gives added insight into what the parts of the brain do and how significant they are.

The large number of connections that are in the child's brain prior to the pruning phase mentioned above lead to a more vivid imagination and this is also why, as people become older and have fewer connections, they appear to have less imagination (Eagleman, 2016).

Teenagers have received a reputation for being risk-takers and careless. This can be explained by the late development of the pre-frontal cortex, the area of the brain which is in charge of impulse control, reasoning and problem solving. Dhal, who is a paediatrician and child psychiatric researcher, says that teenagers find that stress can hinder their decision making, particularly as their frontal lobes are under-developed and these areas would stop their urge for taking risks once mature. This is backed up by Dvorsky (2013) who reports that a study in 2009 found that young teenagers playing a driving game took twice as many risks if their friends were watching and older teenagers took approximately one and a half times more risks when their friends were watching. This peer pressure is comparable to the stress described by Dhal.

Teenagers are four times as likely as older drivers to be involved in a crash and three times as likely to die in an accident according statistics collected by the insurance institute for Highway Safety (Giedd). This further backs up the impact of late development of the pre-frontal cortex. Further research (Feenstra, Ruiter and Kok, 2011) evaluated the reaction times of adults compared to teenagers and found that adults respond on average 110 milliseconds faster in all situations (both risky and non-risky) than teenagers do although both respond faster to risky than non-risky situations. This has a correlation to the number of traffic accidents involving adolescents but the study only looked at males and would need to be extended for the information to be generalizable. Australian law reflects this research as they state that new young drivers with a provisional (P1) licence can only carry one passenger under the age of twenty-one at night (summary from Wikipedia). Crone and Dhal (2012) included taking drugs and drinking in their list of risks taken by adolescents. The problem with drinking and taking drugs is that when a teenager takes the same amount as an adult, it has a larger effect (Forster, 2015) and binge drinking therefore is more likely to lead to brain damage in teenage years.

Steinberg's (2007) research talks about how teenagers' reasoning abilities are just as good as those of an adult by the age of 15, but when they are experiencing emotions or when they are with peers, their reasoning skills fail which is why they are more likely to take risks. The reason for this is that the limbic and paralimbic systems (the reward centres) are more highly developed than the pre-frontal cortex which is the part of the brain that would promote the reasoning skills and regulate the urge to take risks. Vulliamy (2016) describes how the extra hormones being released during puberty make teenagers more prone to feeling stressed, anxious and upset. These emotions are more easily triggered and are more intense because of the increased amounts of testosterone, oestrogen and progesterone. All of this could be triggered by something as simple as a large amount of homework or a sad film. Teenagers in particular struggle with anxiety caused by the hormone allopregnanolone. In adults, this hormone hopes to reduce anxiety but in teenagers not much of it is produced or, when it is produced, it can increase the amount of stress felt. All of these heightened emotions and the difficulty to calm down mean that reasoning is hindered and therefore more risks are taken.

Why is it important for teenagers' brains to be different?

Edmonds (2008) notes that risk taking may be an important evolutionary factor which helps to explain a reason for teenagers' brains working differently to adults'. She says that risk taking in teenage years can also be seen in other species such as birds or penguins when they learn how to fly or swim. Without taking a risk, they wouldn't have the confidence to learn to do these activities and eventually leave the nest to set up an independent life. This is related to human development as if people were not prepared to take the risk of leaving home, they would never be able to live independently.

Vulliamy (2016) describes how the body starts introducing hormones during puberty which promote feelings that increase teenagers' urge to be accepted by their peers. The evolutionary reason for teenagers becoming more sociable is to promote genetic diversity by stopping making such tight links with their family and bonding with others.

I have some questions that may be relevant for future studies (if these are not already taking place);

It is known that puberty is being reached at an earlier age, due to obesity and possibly chemicals and family stress (Maron, 2015). Could the earlier hormone changes affect the onset, speed and duration of brain development? Could this affect the ability of people to develop mature reasoning skills? Could there be more risk takers in future? Could this affect the nature of the risks that are taken? For example perhaps younger risk takers will not be taking drugs or drinking alcohol but instead taking more physical risks such as fighting or climbing trees. If the brain develops faster, could people be more mature during their teenage years? Could this lead to a reduction in the age to vote and drive? If the brain starts maturing earlier but continues to develop for longer, could this lead to an increase in intelligence?

With the increased availability of more advanced technology (hand-held computer devices such as smart phones and tablets), what will be the long term impact on brain development? Will people become more dependent on these items and therefore develop fewer connections in their brains? What will be the impact on intelligence? Could this impact on social life? The elderly population today did not have access to technology while their brains developed so we are unable to see how this might affect them in the future; could this impact on brain degenerative diseases such as dementia?

Conclusion

The evidence we have that teenagers' brains are different to adults' is based on MRI studies which show that teenagers' brains continue to develop through a stage that does not finish until the early twenties. Behavioural studies allow us to link the changes in the brain to those seen in teenagers' behaviour. The scans have shown us that the myelination starts at the back of the brain and works its way towards the front. I have found that one of the last areas of the brain to develop is the prefrontal cortex which plays an important role in reasoning and behavioural regulation. The behavioural studies link the fact that the hormones that are active in the teenage brain make them more likely to experience stronger emotions; they are more likely to take risks as they respond to reward more strongly than adults, and have an urge to be accepted socially. Teenagers need their brains to work differently so that the will take the risk of leaving home and explore new places. They also need to be accepted by their peers and move away from their family so that they can widen the gene pool, preventing in-breeding.

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What evidence do we have that teenagers' brains are different from adults' brains? Why do you think teenagers might need brains which work differently?

A Florida teenager filming himself driving "like an idiot" causes a car accident involving four other vehicles. He's seriously injured, and while in the hospital, he uploads the video of him crashing to YouTube 'for the lols', which amuses his followers in the digital world, but helps police in the real world arrest him for reckless driving. Hoping to simulate the highs of a cocaine hit, schoolchildren in Ohio ended up snorting so many powdered Smarties that letters had to be sent home to parents warning them of the side effects, including nasal maggots. A teenage girl faked her own kidnapping to get her ex-boyfriend's attention after a breakup.

Universally, teenagers are known for doing things that adults find difficult to comprehend. Through intense research, scientists and psychologists have been able to explore the idiosyncrasies of teenage brains and discover how they differ to those of adults. Hopefully, by the end of this essay you will have a deeper and more sympathetic understanding of how teenagers function and why they partake in such ridiculous and often dangerous activities.

Why do teens do stupid things? Surprisingly, research has discovered that teenagers are actually more likely to contemplate the risks and take longer (approximately 170 milliseconds more) weighing the pros and cons of engaging in high-risk behaviour than adults - and actually overestimate the risks. It's just that they often decide that the benefits - the immediate gratification or social acceptance - outweigh the risks.

The reason that teens often over-evaluate decisions is because their frontal lobe (which is where decision making happens) is not as connected to the rest of the brain as it is later on in life. This means that it is virtually impossible for them to come to a conclusion as quickly as adults and are therefore more likely to take a risk. One study using MRI scans on adults and teens enabled scientists to see that teenage brains reacted very differently while making a decision while friends were present. The study demonstrated that teenagers who wouldn't take risks when alone or with an adult were far more likely to take risks when their peers were watching.

The scans unveiled that the reward centre of the adolescent brain became much more active in the in the company of peers. In the adult's brain, however, the reward centre's activity remained at a constant level despite changed audiences. An explanation for this is that not feeling accepted by others can make teens feel unworthy and anxious.

Although this factor of puberty seems unreasonable, scientists have pinpointed an evolutionary reason. It is vital for teens to socialise and interact with people other than their family after reaching sexual maturity in order to avoid and reduce inbreeding and encourage genetic diversity.

These fundamental scientific differences have led to a debate within the legal system, as to whether juveniles should be regarded as being fully culpable for crimes they have committed. According to an online article posted by the Harvard Medical School, crime rates peak in the late teenage years and then decline by the early 20s.

Evidence that adolescent brains and adult brains are completely disparate has influenced the United States' Supreme Court's view that juveniles should be treated dissimilarly from grown-ups by the justice system. This means that anyone who commits a crime while under the age of 18 is no longer a candidate for execution or a mandatory life sentence without parole due to their adolescence, enabling them to be deemed as having an underdeveloped sense of maturity.

However, given a sense of autonomous morality is supposedly fully developed by the age of ten (according to the famous child development psychologist, Jean Piaget) why are teenagers so likely to commit crimes? Neuroimaging research has clarified that it is the adolescent's vulnerability to reward that drives them to perform bad or risky behaviour. They can often recognize risks, but incomplete development of brain mechanisms related to modulation of impulsive behaviour reduces their tendency to consider those risks.

Not only do teenagers possess brains that function in a way that exposes them to taking risks, they also have to face a constant battle with hormones while enduring puberty. Hormones are chemical messengers in the body that are created in the endocrine glands. They control most major bodily functions, from simple basic needs like hunger to complex systems like reproduction, and emotions and mood. During puberty, hormones often cause emotions to be amplified; a combination of risky behaviour and amplified anger is a recipe for crime. Although it is fair for teenagers to be held accountable for their crimes, extenuating circumstances should be considered due to their inability to resist risk taking and ignore their overwhelming emotions.

Another explanation as to why teenagers have such a desire to take risks is because they thrive on the thrill and adrenaline rush that they experience when breaking the rules. An enhanced dopamine release that adolescents endure causes them to gravitate towards thrilling experiences and exhilarating sensations. Research also suggests that the baseline level of dopamine is lower—but its release in response to experience is higher—which can also explain why teens may report a feeling of being 'bored' unless they are engaging in stimulating and novel activities.

A second way in which an increased dopamine release affects teenagers during adolescence is their documented increase in susceptibility to addiction. All behaviours and substances that are addictive involve the release of dopamine. Not only are teens more likely to experiment with new experiences but they are also more prone to respond with a robust dopamine release that can become part of an addictive cycle. A drug like alcohol for example, can lead to the release of dopamine, and teenagers can feel compelled to ingest beer, wine or spirits. When the alcohol wears off, dopamine levels plummet. They are then driven to use more of the substance that initiated their dopamine circuits to stimulate the feeling of high dopamine levels again. The teenage years are a period of low dopamine release so when adolescents experience high release of dopamine, they crave more of it because the intensity seems stronger than it actually is due to them not experiencing it often.

Why are teenagers so moody? This is another question asked by adults who seek an explanation as to why their adolescent children tell them they hate them, get unnecessarily upset and have petulant tantrums. Although teenagers can be labelled as impulsive and self-centred, neuroscience has been able to uncover the answer for the following question – is it actually their fault? It is thought that oestrogen and testosterone, which are sex hormones, affect teen brains and contribute to moodiness during adolescent years. Although hormones lead to problems involving grumpiness, surprisingly, it isn't just these hormones that are linked to a teenager's unpleasant attitude.

When in times of stress, the body releases a hormone called allopregnanolone. Recent research has shown that for adults, the release of this hormone has a calming affect whereas in teens it can result in an increase in anxiety. Anxiety is commonly associated with anger as when you are stressed you are more susceptible to feelings of irritation. When a teenager is stressed, they are likely to be more indignant than the average adult. This reaction to allopregnanolone tends to disappear as teens approach adulthood, which has an outcome of fewer moody episodes throughout stressful times.

Other changes in teenager's lives also contribute to their mood swings. Throughout puberty, teens' physical appearance changes rapidly; this can result in them feeling much more self-conscious and hiding from the outside world, often shut away in their bedrooms on screens. A UK study funded by the Unilever detergent brand, Persil, as part of the Dirt Is Good campaign discovered that three quarters of British children spend less time outdoors each day than prison inmates. In a Guardian article about the study, Mark Sears of The Wild Network said: ‘The truth is we are enclosing our children. We are stifling their ability to be free, to be at their best as children and it is having significant impacts.’ He suggested that increasing obesity and lower mental wellbeing in children was linked to a lack of physical activity.

Isolation can also encourage anti-social behaviour, which can cause teens to develop poor socialization skills. Teenager’s with poor socialization skills are less likely to form stable intimate relationships as adults and are more likely to experience peer rejection (which enables teens to feel unworthy). Social skills in schools impact safety as well as interpersonal interactions; this is because students who lack good social skills are more likely to demonstrate aggressive or violent behaviour. They are also less likely to self-regulate their behaviour and have difficulties asking or accepting help from peers which can generate violent responses to conflict.

Another factor that is affected by anti-social behaviour is academic performance. Students who are shunned by their peers develop self-esteem issues and depression which causes them to deflect their efforts away from academic achievement.

Another explanation for teenagers underachieving in school is because of their ‘lazy’ tendencies, but again, is it their fault? Teenagers release melatonin (the ‘sleepy’ hormone) a few hours later in the day than adults and so are able to stay up later but then need more sleep in the morning. Traditionally, school start times range from 8-9am across the United Kingdom which, according to professor of cognitive neuroscience Sarah-Jayne Blackmore, is ‘practically the middle of the night for teenagers’. These early start times discourage productivity at school as teens find it hard to work to the best of their ability when tired. Adolescents often experience what is known as ‘social jetlag’ as a consequence of being forced to awaken so early which explains the long lie-ins at the weekends.

Early school start times are not the only reason that teenagers are sleep deprived; the use of screen based technology contributes greatly to why teens don’t get enough sleep. A psychologist named Professor Foster from Oxford University mentioned in a BBC online article that "The great problem with teenagers is that you're not only biologically programmed to go to bed late and get up late, but there's also many attractions like gaming and Facebook and texting and many teenagers are doing this into the early hours of the morning and delaying sleep even further."

However, although the concept of teens staying up late to continue to go on their devices contributes to sleep deprivation, it is also simply looking at a bright screen that also has an impact. The brightness of phone screens can often interfere with the human body clock: looking at a lit up screen late at night can trick the brain into thinking it is daytime because it is hard to differentiate artificial light with daylight.

This means that going on a device before bed can disrupt the intensity of your sleep and has a detrimental effect on how alert and fully-functioning you are. Simon Shepard, the CEO of fitness tracking company Optima Life, told me in a phone interview: ‘Mobile phone and tablet screens give out a blue light which stimulates the pineal gland, causing the release of dopamine, which is a neurotransmitter that makes us feel alert. This is the last thing teenagers need before trying to go to sleep’.

It is a well-known fact that a substantial amount of sleep is crucial to maintain a healthy lifestyle, but for adolescents it is even more important. Lack of sleep affects growth, and also things like memory consolidation. Without enough sleep, short term memory doesn't consolidate into long term memory which of course would have a negative impact on school grades and academic success. Psychologist Jane Ansell set up the charity Sleep Scotland to help children with special needs establish good sleeping patterns. A recent survey taken for her charity stated that three

Scottish schools suggested 52% of teenagers were sleep deprived, and about 20% were reported falling asleep in class at least once in the last two weeks. This is further evidence to reinforce that teenagers are not lazy and do not possess a 'can't be bothered' attitude, but rather, they don't receive enough sleep to perform to the best of their ability.

Stuck in the middle of being a child and an adult, many teenagers get frustrated. Their bodies have developed adult capabilities, but the adult world is not ready to welcome them yet. The teenage brain needs to work differently, because it performs a vital function in making the transition from childhood to adulthood. The human brain circuitry is not mature until the early 20s. An article featured on the Harvard Medical School website states that, 'Among the last connections to be fully established are the links between the prefrontal cortex, seat of judgment and problem-solving, and the emotional centres in the limbic system, especially the amygdala. These links are critical for emotional learning and high-level selfregulation.'

The article explains that throughout puberty the brain is effectively reshaped: 'Neurons and synapses multiply in the cerebral cortex and are gradually cropped throughout adolescence. Eventually, more than 40% of all synapses are eliminated, largely in the frontal lobes. Meanwhile, the white insulating coat of myelin on the axons that carry signals between nerve cells continues to accumulate, gradually improving the precision and efficiency of neuronal communication — a process not completed until the early 20s. The corpus callosum, which connects the right and left hemispheres of the brain, consists mostly of this white matter.'

Another circuit still under construction in adolescence links the prefrontal cortex to the midbrain reward system, where addictive drugs and romantic love exert their powers. Hormonal changes are at work, too. The adolescent brain pours out adrenal stress hormones, sex hormones, and growth hormone, which in turn influence brain development.

Fundamentally, the adolescent brain serves as a biological bridge that helps children transition into fully fledged adults. Although this period in a human's life can be stressful, overwhelming and hard to deal with at times, it is a course that is essential for people's development and is somewhat inevitable. Men are from Mars and Women Are From Venus is a bestselling book about adult relationships being affected by the differences between male and female brains. Internationally it has sold over 50 million copies. I would argue that if men are indeed from Mars and women are from Venus, then teenagers must be from Neptune.

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Discrepancies between the teenage and adult brain: Analysis of existing evidence and the rationale behind the chaos

"What is wrong with you?" The all–too–familiar outburst of a frustrated parent unable to understand their teen child. The word "teenager" has fairly negative connotations: moody, stroppy and lazy are some words that may come to mind. These descriptions are seemingly reserved only for teens but is it their fault? The transition from adulthood to childhood is something all teenagers must suffer through. Several years of physical growing pains are accompanied by subtler neural ones. A common sense response may be that the only divider between teens and adults is the size of their brains. Adults just have bigger brains than teenagers. Bigger equals better. By better, I mean better at making decisions, better at managing money and all the adult things thinkable. Yet, upon closer inspection, the human brain is over 98%[1] its full size at the point of adolescence; so other changes within the brain must be occurring to change so drastically the psychology of teenagers during those developmental years.

A superficial side-by-side comparison between teenagers and adults may go something like this: the adult is rational and prudent, self-sufficient and responsible, but most importantly a functioning member of society. Teenagers, on the other hand, are deemed to be dominated by the desire to please their peers, without fully being aware of any repercussions. While not fully accurate, this is the picture painted to express the differences between the two phases of human development. Delving deeper into brain anatomy, we see that adult brains have a more developed pre-frontal cortex.[2] This frontal region of the brain is responsible for the control of impulses, forming judgements, planning and moderating social behaviour – the "cool cucumber" under duress. Teenage brains may not operate this way. The pre-frontal cortex (PFC) may not be fully developed until humans reach their mid-20s[3], meaning teenagers are forced to operate without the full help of this guideline. The result: frequent nights being spent passed out on the floor after a few too many shots and having a Master's degree in procrastination. So it seems the pre-frontal cortex seems to be the key to maturing into an adult. However, it begs the question of whether that truly is the sole reason for the discrepancy between teenagers and adults. Would a diminished or damaged pre-frontal cortex result in a relapse into adolescent behaviour in humans? Anecdotal evidence, specifically the case of Phineas Gage[4], shows that PFC damage can lead to emotional instability. His friends noted that after the incident of having a rod shoot through his face and brain he displayed some socially inappropriate behaviour; not unlike that of a teenager. This suggests that without a fully operational PFC, it is harder for teens to moderate behaviour which adults seem to have mastered so well and teenagers sometimes struggle with. Put simply, their brains are like Lamborghinis with weak brake pads. The power is there but the control is lacking.

So without a mature PFC in place to guide teenage actions, most decisions are routed to the amygdala. This archaic region of the brain is associated with primitive impulses of aggression, anger and fear[5] - a kind of gut reaction area which teenagers frequently use. This means that where adults may process a decision through their PFC, teen brains re-route it to the amygdala[6],

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[1] https://faculty.washington.edu/chudler/dev.html
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which leads to some interesting results to say the least. That's not to say they don't ever use their pre-frontal cortex for making decisions; rather, it is something the teenage brain avoids possibly due to incomplete functionality. A group of researchers compared how teenagers and adults perceive emotions by asking them to identify the emotion on a face. They compared brain activity using fMRI. The results showed that the centre of activity was more prominent in the amygdala with teens compared to adults, who used their pre-frontal cortex more[7]. Despite constituting a small sample size of 34 participants, it provided more clarity into the causes of variance between teenagers and adults. If more studies were to be done to strengthen the "re-routing through the amygdala" theory, it would help support the argument. Though not compelling evidence, the study shows that there may be an important link between the pathways the brain takes and the resulting response. However, this study used a cross-sectional design so is therefore still unknown to what extent PFC and amygdala stimulation vary during the adolescent period.

While obvious teenagers and adults typically don't think alike, part of that is attributed to the different sections of teen brains not connected in the way they will be once mature. More specifically, they lack the nerve connections tying the frontal lobe to the remaining brain[8]. Since the pre-frontal cortex is in the frontal lobe, they aren't able to think ahead as effectively as adults can. As the lines of communication in teenagers continue to develop and differentiate, this results in a relatively slow transmission speed between neurons. The solution? Myelin. As the human brain grows, axons within the brain become more insulated by a fatty layer called the "Myelin Sheath". As a result, adult brains have a larger proportion of myelinated axons than their teenage counterparts. Myelin is found in the white matter areas of the brain which is why adults have a larger volume of white matter than teenagers do; this helps them to make faster decisions. Axons insulated by myelin communicate smoothly throughout the brain: the more myelin, the smoother and more efficient[9] the brain becomes at conducting electrical impulses. The myelination process, though not strictly region specific, tends to start towards the back areas of the brain before moving to the frontal regions. In other words, the PFC is one of the last regions to be hooked up, leaving a few years waiting period for it to reach optimal functionality. Some studies[10] show us that white matter increases as we age. Therefore, adults have more white matter than teens, which may be able to explain why they have better executive function, i.e. planning, reasoning and decision-making skills, than teenagers. But even with insulated neurons to deliver that boost in thinking, is it enough to drive the change into adulthood from adolescence? Personally, I think it is. The data[11] we have point to a more mature frontal lobe, where the PFC is located, improving your ability to make good decisions and plan ahead. That region of the brain isn't fully developed until around age 25 so teenagers still have a lot of developing left to do compared to adults.

Undoubtedly, adolescence is a time where reward-seeking behaviour is at its peak. Some hypothesize[12] that the ventral striatum within the brain - a part of the reward system - is hypoactive during those teens years, leading to elevated reward-seeking behaviour to reach the same level of stimulation as adults do. On the contrary, others say that this region is hyperactive resulting in more reward seeking. Both have their merits but the latter has more compelling evidence to support their hypothesis. Once again, going back to the fMRI, once presented with a big potential reward, teenage brains "light up" more than adults and children[13]. However, when a small reward was offered, there was very little neural stimulation. Simply put, this revealed that it takes a lot for

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7 http://www.sciencedirect.com/science/article/pii/S1878929312000801
8 https://www.youtube.com/watch?v=hiduiTq1ei8
9 http://www.jneurosci.org/content/28/38/9519.full
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them to get going but once they are engaged, they respond better than adults. While some parts of the teen brain aren't fully developed, their "Nucleus Accumbens" forms early on; a part of the Pleasure-Reward Zone within the striatum. What this means for teenagers is that their brains are more attuned to their reward centre as it is a more influential part of their brain than in adults. Another study carried out by developmental psychologist Laurence Steinberg[14] at Temple University had teenagers do a simulated high-risk driving under fMRI. The results showed their reward system of their brains lit up more when they thought another teenager was watching, which directly correlated them to taking more risks. This supports the hypo-activity of the ventral striatum theory; teenagers need to be riskier than adults to get the same thrill. So adolescents may be reckless not because they underestimate risk, but rather over estimate rewards - at least more than adults do. However, the problem with these kinds of studies is that they usually have the participants perform only one or two tasks. There is a general pattern of teenagers showing heightened neural activity within the striatal area but more data needs to be collected to improve understanding. It is especially difficult to interpret data about the brain, which is a complex machine. The above study mentioned was performed in 2012; perhaps our knowledge on the physiology of the brain has changed since then. It wouldn't be too much of a stretch to presume that teenagers of today's age may possibly be even more reward–hungry than before – a consequence of the hyper-expansion of social media. More recent studies would need to be carried out to challenge or support this hypothesis.

During the teenage period, teenage brains undergo a process unique to them. Their brains start thinning out as well as building themselves. This process, known as "synaptic pruning"[15], occurs during the early years of teenage-hood, where the brain starts to lose unused synaptic connections, specifically in the grey matter areas. This phase brings about an interesting "use it or lose it" principle; the idea is to hardwire synapses in a useful way (learning a language, playing an instrument, sports etc.) so that our brain topiary is given a lasting shape. MRI scans show that as teens approach adulthood, the amount of grey matter decreases[16] as neural connections are pruned away. Unfortunately, the window of elasticity is usually only open during the adolescent period. Grey matter contains most of the brain's neuronal cell bodies, meaning that fundamental human abilities – perception, speech, reasoning etc. – are processed within that area only. If unused connections are severed, it may become more difficult for adults to handle new skills with the same ease as teenagers do. The learning process[17] itself consists of the repeated firing of neurotransmitters between neurons, which is rendered more efficient after mastery. Possessing more raw material, i.e. grey matter, available during this process could make it easier – the brain simply has more neurons to draw upon. That is not to say adults cannot learn new things after adolescence, but it can be harder because they don't have the same neural flexibility that teenagers possess. Therefore, if a teen is engaging their brain through academic stimulation or music, those are the synaptic connections that will be retained. If they are on the sofa, or watching cat videos on YouTube, those are the cells likely to remain. The brain has given us the chance to become great if watered by new skills and talents; if left dry and disengaged it becomes more static. Much of what we have learnt about this process and changes within the brain during adolescence is relatively new. The data however, offers a good explanation as to why it is easier for teens to pick up new skills than adults. But the brain is still very intricate and what controls the mechanisms of the pruning process is still not fully understood.

[14] L Steinberg - Developmental review, 2008 – Elsevier: A social neuroscience perspective on adolescent risk-taking
[15] https://faculty.washington.edu/chudler/plast.html
[16] http://www.edinformatics.com/news/teenage_brains.htm
[17] http://lifehacker.com/the-science-behind-how-we-learn-new-skills-908488422

One fascinating niche yet to be fully scrutinised by researchers is the role of hormones during the development of the adolescent brain. Their brains stimulate the release of more adrenal and sex hormones during this time, specifically: oestrogen, testosterone and cortisol.[18] Popular culture has trained us to believe that these molecules are a big part of the erratic teenage behaviour; yet, existing data point to increased hormonal levels having a weak correlation[19] to adolescent behaviour. Therefore, it would be inaccurate to believe adults conduct themselves more sensibly because their brains trigger less of these hormones – their effects are not prominent behaviour-wise. What this could suggest though, is that the relationship between the two variables are more complex. The balance of hormones is a system deeply embedded within layers of elaborate neural structures. There is still room for more studies to be performed; what they reveal could show us whether hormonal regulation by the brain is another plausible cause of variance between teenager and adult behaviour.

Relatively new evidence concerning the role of the cerebellum (little brain) in cognition has given more insight into the development of the brain. Once it was regarded as being quite disengaged with the forebrain; however, recent work reveals that it could be regularly interacting with this region[20]. The cerebellum is one of the areas of the brain still developing until one's 20s so there must be some differences between the teenage and adult cerebellum. It is an area involving higher cognitive functions[21]. Perhaps the reason why adults are able to perform better than teens in activities requiring "more brain power", e.g. problem-solving, is due to their more mature cerebellum. Nonetheless, we don't have enough conclusive evidence yet to appreciate fully the complexity of the cerebellum and its role in adolescent development.

To conclude, it could be argued that the dissimilarities between the teen and adult are necessary. If they both anatomically shared the same brain, the world be quite dull, to say the least. The quintessential teenage arrogance would be replaced by a placidity only adults seem to possess. In the evolutionary world, how could these teenage traits survive if they weren't useful in some way? The emotional and motivational system that shifts away from the family and more towards social peers during adolescence makes sense in evolutionary terms. The real world involves dealing with people you don't really know; being bold and audacious, therefore, can be a good thing. With a new-found capacity for change teens are empowered during a time when plasticity in cognitive and emotional function is enhanced. It is documented that humans have a long adolescent period relative to other animals but this allows teens to be more adaptable in the outer world because their brains are kept supple for longer. This encourages ingenuity within the human species that gives us our unique position in the animal kingdom. That is not to say every teen is perfectly designed to be massively influential; we all know that's not the case. But it is a good thing that their brains are malleable so that they can stretch and defy what they know about society and find their niche within it as adults.

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[18] http://www.health.harvard.edu/mind-and-mood/the-adolescent-brain-beyond-raging-hormones

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In defense of the teenage brain

Yobs, slobs and hoodlums. Teenagers today and throughout history have been reviled for being lazy, disorganised and reckless. Even Shakespeare had words to say on the matter: "I would there were no age between ten and three-and-twenty, or that youth would sleep out the rest; for there is nothing in the between but getting wenches with child, wronging the ancientry, stealing, fighting."

Girls are criticised for being too concerned with personal hygiene; boys for not being enough so. They're far too social – but not in the right way, of course, because they don't know how to connect with others in the *real* world. Parents across the country wring their hands over lost keys, unwashed socks and moodiness.

In the media it is worse. Newspaper headlines focus on gangs, drugs and brutal attacks on pensioners. Like most media stereotypes, these are highly sensationalised accounts of a few isolated incidents taken completely out of context. There is no denying that these articles and 'studies' are both unfair and warped wildly out of proportion.

"Idle youth: Teenagers today are too lazy to baby-sit!" This shocking revelation from the Daily Mail was based on the journalist's personal experience of putting up a card in a local newsagent and getting replies only from "grans or mums".
"So many young adults today are selfish monsters." This gem (also from the Daily Mail) was written about unpaid interns living with their parents, and based on the generation and age group that produced Malala Yousafzai.

However, there are some convincing arguments involving statistics more reliable than those used by the Daily Mail. Number of deaths by reckless behaviour rise dramatically among teenagers and then fall again in later years. So do crime rates – and when the unwashed socks are taken into account…

The demonisation of teenagers, much like any demonisation, is clearly still unjust. But in recent years new research has been done into the brains of a wide range of age groups, including teenagers. Magnetic resonance imaging (MRI) scans have been used to investigate both the structure and function of our most mysterious organ at various critical stages. What scientists have discovered in these investigations has gone a long way to explaining the seemingly irrational and reckless behaviour exhibited by teenagers, and explained away by 'hormones'. Of course, this research is far from complete. The human brain has been heralded as the most complex structure in the known universe; in other words, we know more about what goes on around 11 billion miles away than what goes on inside our own heads. It is still very possible that many other factors we have yet to discover play a huge part in what we do and why we do it.

However, until much of this very recent research had been completed, it was widely assumed that the brain was pretty much completely developed by the time we reached adolescence. This is not the case. Most scientists agree that the brain is still maturing – at the very least – until our mid twenties.

There is a region in the brain called the pre-frontal cortex. This is where much of our most advanced thinking goes on. It is used for future planning and decision making, which stops us doing reckless things, social risk assessment, which stops us doing reckless things and being hideously embarrassing, and social interaction, which stops us doing reckless things, being hideously embarrassing and alienating ourselves forever. Or rather, it should stop us doing these things. As we all know, sometimes things don't go quite to plan.

Unsurprisingly then, the pre-frontal cortex is one of the areas in the brain that undergoes the most significant changes during adolescence. But what is actually happening to this infamous pre-frontal cortex as it develops?

Grey matter is a tissue in the brain, made up mainly of nerve cell bodies (the rounded part of the cell which contains the nucleus of the cell) and dendrites (which are like the branches of the cell). White matter is another kind of tissue in the brain, made up of nerve fibres (the long, thread like extension of a nerve cell, formed by something called an axon) and the 'myelin sheaths' (the insulation on a nerve fibre).

The brain at work consists of many different regions connecting and passing messages on through nerve impulses. Nerve impulses are electrical signals that are translated as information for the brain. A way to get your head around this process is to think of it as a city, with different areas of the city as the regions of the brain and cars as nerve impulses. The nerve impulse travels along the axon of the nerve fibre, which is coated in myelin to allow smoother passage for the nerve impulse. Think of it as a newly laid road to help the car drive more easily than on rough ground. A cluster of nerve fibres and their sheaths make up a nerve cell, also known as a neuron.

When the nerve impulse reaches the end of the fibre, it triggers the release of a chemical known as a neurotransmitter. This substance allows the nerve impulse to diffuse across a synapse (a tiny gap between two neurons which the nerve impulse has to get across, transferring it to another nerve fibre). Imagine a policeman as a neurotransmitter, waving the car across a busy junction (the synapse) to get to a different road.

One of the ways in which the teenage brain matures is through the development of myelin. Just like a badly planned road works, the nerve fibres are 'paved' with this crucial substance from the back of the brain first, working their way forwards. This means that the higher level thinking areas towards the front are connected with these pathways later than the rest of the brain, so cognitive processes like risk assessment and future planning aren't matured at the same as the rest of the brain, because the critical regions of the brain aren't properly linked up yet.

During adolescence, the total volume of grey matter in the brain decreases through a process known as synaptic pruning. The brain analyses which of these junctions are used frequently and which are not, to determine which pathways in the brain are more important. The synapses that are being used are strengthened, the ones that are not are 'pruned'. This sounds like a painful and unnecessary process, but this is not the case. Synaptic pruning makes the brain overall a more efficient and capable machine – like dead heading flowers, sacrificing the weaker blooms makes the overall plant stronger.

However, this also means that what goes on in the brain is very dependent on the environment the adolescent is in. The teenage brain is known for being very malleable: it's primed for soaking up information and learning new behaviours, and it can be influenced very easily. This is why young people are more vulnerable to addiction than their parents, and on a slightly more positive note, why they are better at learning foreign languages. This is because synaptic pruning is going on, and the brain is working out which roads should be developed into main ones, and which are unnecessary back alleys that can be cut altogether. Different environments will challenge and use different parts of the brain, so the kind and level of synaptic pruning which is going on depends on where you are, who you spend time with and what you use your brain for. For example, children who grow up practising the piano for several hours every week will undergo a different process to children living in indigenous communities who help to gather food every day.

This is more or less how the adult and teenage brains differ. The average adult brain, however old that might be, is fully connected with myelin coated nerve fibres. It also has its biggest synaptic pruning job done. The adult brain is more efficient and fine tuned to whichever path in life it has taken, whereas the teenage brain is still considering its possibilities and working out which path it will likely take based on previous brain activity. For example, is it likely that it will need the crucial pathways to becoming a concert pianist?

Coming back to unwashed socks (again), these discoveries into how the brain works have helped us understand the many mysteries of the adolescent. The pre-frontal cortex is still a relatively unexplored area for the teenage brain, because it drew the short straw on the waiting list of those physical developments we heard about earlier. It isn't a key player yet.

However, while science has moved on, the rest of the world hasn't. Yes, teenagers can be annoying, but as we have learnt, it isn't their fault, and the world isn't particularly accommodating of them, which doesn't help matters. Our laws are based on factors and opinions shaped by ideas from decades ago, when we definitely didn't have the technology we do today to understand the little we do now about the brain. Legislation isn't even consistently unscientific, and within one country there are countless contradictions.

An example of the contradictory nature of our laws: some 16 year olds who work are required to pay a certain level of tax, but can't vote. No taxation without representation, surely?

We assume it would be impractical and unfair to raise minimum ages to 25, say, or even later. To some degree, this is definitely the case. While adolescents don't have the full capacity to make rational judgments and plan for the future, some issues just aren't particularly relevant. It doesn't seem fair to allow young adults to be functioning members of society in some ways, by working for example, but not to allow them to participate in our democratic system. Also, dodgy haircuts and reckless driving are separate problems and not transferable arguments to understanding the various merits of political candidates and their policies.

However, in some cases the arguments are wholly relevant and definitely transferable. Furthermore, our opinions and expectations are shaped heavily by culture and what is normal to us. It is very possible that to many Angolans, for example, the age of consent in South Korea is just bizarre. In South Korea it is 20 years old. In Angola it is just 12.

The army, based on what we now know about risk assessment and reckless behaviour in the teenage brain, seems a wholly unsuitable job for an adolescent. Particularly when you take into consideration the nature of a job in the army, which isn't like most other jobs in that it is extremely difficult to leave unless you have the money to 'buy yourself out'. Yet you can join up for the army at just 16 years of age… and while now only 18 year olds can be sent to the front lines, this doesn't seem much better taking into account the development of the pre-frontal cortex. This seems detrimental not only to the health and safety of the adolescent, but to the army as well.

In defence of the teenage brain: an organ hated by the media and society alike, labelled lazy, selfish and monstrous, and made vulnerable by the misguided laws that aim to protect it. For all that, it is a stepping-stone on the path to adulthood, without which we would be lost. But yes… the teenage brain is the cause of quite a few unwashed socks.

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What Evidence Do We Have That Teenager's Brains Are Different From Adult Brains? Briefly Why Do You Think Teens Brains Need To Work Differently?

The human brain; at the centre of our nervous system, it is without a doubt the most complex organ in the human body. Scientists have studied the brain for centuries but it is only recently that they have discovered the development and changes that occur from birth up until adulthood. A stage in life that has particularly amazed many across the globe is the teenage and adolescent years. It is one of the most crucial epochs of our lives concerning development and future shaping of the brain and it is thus extremely important that teens themselves understand how their brains are different from adults. Lots of evidence has been gathered from studies and health articles discussing this topic and the following essay will include many of these.

Many people link teenagers with traits such as laziness, being moody and the ever-famous indecisiveness. The latter having a very clear reason as to why it is common amongst those at this age. The prefrontal cortex is the part of the brain located in the frontal lobe within the cerebral cortex. It is responsible for executive functions such as planning, establishing right from wrong and reasonable thought. However, studies show that it is the last part of the brain to fully develop and doesn't do so until the mid-20s. The limbic system, on the other hand, is fully matured by teen years and ironically controls emotion. A study conducted found this to be correct based on a principal understanding that the brain matures in a specific way; it starts from the back and the inside of the brain and over time to the front and the outer regions. Consequently, when teens are asked to respond to a situation, they seem to be more inclined to rush into their decision which usually results in an emotionally charged response in favour of a logical one.

Another study was directed whereby both teens and adults were shown the same pictures of "emotions" and were asked to determine each one. The results showed that 100% of the adults correctly guessed the emotions whereas only 50% of the teens guessed correctly. MRI imaging showed that during the experiment, the amygdala (a part of the limbic system) was more active in the teens than in the adults which concluded why the teens did not make a logical response.

Teens are also at a stage in their life where they think it is appropriate to take unnecessary risks but again there is a valid reason why this seems to be mutual amongst teenagers. The reward centre is home to the chemical "dopamine" which transmits signals in the brain that makes people feel happy. The number of brain receptors interacting with dopamine is much higher in a teen that in any other stage of their lives therefore when they are exposed to a potential reward such as a compliment, this part of the brain reacts strongly, more so than an adult's brain would. Dopamine is also a precursor of adrenaline which is what makes a person take the action towards a reward. Hyper-rational thinking also plays a key part in this. It is the process whereby the part of the brain responsible for considering pros and cons is favoured towards the excitement of the pros and therefore underestimates the consequence of the pro. When this is paired with the already high dopamine levels in a teen, it becomes all the more dangerous.

Evidence shows that peer pressure, likewise, is a factor that constitutes towards risky decisions. When teens and adults were put into a driving simulator they both took the same number of risks when on their own but once they were each accompanied by friends, the teens took considerably more risks than the adults did. Analysis showed that this was because the teens' reward centre was even more active when they were around others.

Another study was undertaken by UCLA Brain Mapping Centre where fMRI scanners were used to see how social media affected teens' brains. When considering likes, the nucleus accumbens region of the brain (situated in the reward centre) was quick to light up. Scientists came to the conclusion that this was what was encouraging teens to use social media increasingly more often. What came as a surprise was that the teenagers were more likely to “like” photos based on their popularity showing that, yet again, they were more driven towards peer pressure similar to the study mentioned above.

Another area that victimises humans in general is addiction but in teens, it is proved to have a much worse effect than adults and this is all down to their brains. When going through a stage of immense growth, drugs and alcohol are known to merely stunt their development further. Evidence shows why teens are more vulnerable to the effects of alcohol and drugs than adults are; the DNA in a teenager is much looser than that of adults and this is so they can infuse new experiences into their brains. Evidence from Dunedin Longitudinal Study concludes that the teenage brain is predominantly sensitive to environmental input. Those younger than 18 who are experimenting with drugs and alcohol have a 25% chance of becoming addicted to the substances compared to those over this age which have a much smaller 4% chance. Alcohol triggers a dopamine rush so the desire for satisfaction grows. This paired with teens’ already increased levels make it all the more precarious for themselves both externally through physical means and mentally within the brain.

Through alcohol, the dopamine is released unnaturally meaning the natural levels are decreased denoting the reason why a person becomes more reliant on alcohol to provide for them. Alcohol is also proven to affect the frontal lobes which as mentioned is continuing to develop in a teen day by day and ultimately cannot afford to be damaged as it is predominantly setting themselves up for their future lives. Excessive consumption also shrinks the hippocampus which results in limited short-term memory ergo affecting a teen’s academic success in the long term.

Nevertheless, we cannot forget that there is a vital reason why teenagers need a brain that works differently to adults as it is a crucial time for brain development. Teenagers need a brain which works differently so that they can learn to grow independence from their caregivers and it is from the processes and consequences that have been mentioned that help them to do so. While this is palpable, it is distinguishing what is right from wrong where many seem to stumble. For example, peer pressure can incur both positive and negative outcomes. If those around a teen are encouraging them to participate in a new activity or venture into a new and beneficial skill it immediately puts them in a healthier position but if their peers are encouraging them to take risks that will, in fact, be a hindrance to them such as drugs and alcohol then it is these habits that the teenage brain will make sure to continue into the future by a process called synaptic pruning.

Synaptic pruning is the process where the brain discards of synaptic connections that are not used as commonly as those that are. In such a way, teenagers are able to shape their own development based on what they do during this period of time; another reason as to why they require brains that work differently. Establishing beneficial synaptic connections will allow for a more advantageous development for the future. Some of those that are considered to be valuable are skills such as learning to play an instrument, a new language and making a habit of frequent reading. All of which require the use of the whole brain and predominantly those parts that are not used in day to day life.

Myelination is the process that occurs after synaptic pruning. Myelin is a healthy sheath that connects synaptically interconnected neurones and makes general communication between the nerves in their brain and thus teenagers more efficient due to it being much faster. The speed at which the signals travel down the insulated axons is now 100 times faster and the refractory (resting) period becomes 30 times faster. Hence, the myelinated circuits are 3000 times more efficiently coordinated which makes the brain more integrated and primed to learn and memorise things faster. This process usually occurs towards late teen years and into early adolescence which is the reason why people seem to see a sense of maturity gradually emerge in teenagers rather than in a single sudden instance.

Sleep is essential for nurturing the brain and allowing it to rest and recuperate, so it comes as a shock that teens are the prime sufferers of sleep deprivation. A normal sleep pattern is regulated by cortisol, a daytime release which helps you to wake up, and melatonin which helps you fall asleep once it gets dark. Studies on the brain show that during puberty, the clocks are pushed back; where adults' melatonin release generally occurs at 10pm, in a teenager it isn't released until close to 1am. Although many would now adopt this as their excuse as to why they were browsing social media well into the early morning, complimentary studies do in fact show that digital devices delay the release of melatonin. Therefore, it is extremely important for teenagers to get adequate sleep to allow their brain to process through all the changes it has to regulate.

For these reasons, it is in fact exceedingly important that a teens brains is different from an adult's and also from their childhood brains as it is at this time of their lives that they are readying themselves for the future and putting their brains at their absolute optimum. A myth amongst researchers and scientists that has recently been eradicated is that the brain's peak development occurs from birth through to the age of 3. However, it is from the recent influx in the interest of the teen and adolescent brain that both stages of development have been found to be equally important in a person's life. Consequently, it is crucial that teenagers themselves understand these changes that are occurring so that they can make the most suitable and well-thought decisions possible. The brain is not yet fully mature so the teenage years are a time where independence can be established as the brain is at its most adaptable. All of the changes mentioned that are undergoing in the teenage brain work together in harmony with one another so it is highly likely that once one aspect begins to fall many of the rest will fall as a result. Take alcohol addiction as a prime example of this. It makes a teenager more reliant on artificial dopamine thus resulting in worsened decisions, putting themselves at a noticeably higher risk in addition to stunting the growth of their prefrontal cortex. Moreover, it means that during pruning, it's these habits that the teenager will continue into their future which are undoubtedly not beneficial. As itemised throughout, numerous quantities of evidence have been gathered to support all the information concluded by scientists and lectures have been held for youths to understand all of these changes that are causing their myriad of common traits. It is from these forms of communication that teens are becoming more and more aware of the changes that are arising in their brains and subsequently taking action towards how they can make their development as unsurpassable as is humanly possible! The brain is an amazing place home to everything that we as humans do. It goes through prodigious changes throughout its lifetime and makes the very best people the way they are. The changes that occur during the teen years as mentioned are those that are known to be the most important that any human will experience in their life. From the early development of the limbic system to the synaptic pruning of the brain, it is a time where teenagers are maturing as the days go by and all the decisions they make will constitute to how they ascend into adulthood.

So despite all the public outbursts, the stomping and the bellowing, there is a lot more going on in a teenagers head that accounts for all these forms of anger and the growing number of trivial mistakes, because in the long-run it is proving to be helping them to not only discover themselves as mature beings but also emerge from the downfalls they encounter and into adults that are able to make reasonable decisions, get out of bed on time and are ultimately equipped for the world they are faced with. Wholly down to the truly magnificent and categorically outstanding mechanical wonderland that is the human brain.

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What evidence do we have that teenagers' brains are different from adults' brains? Briefly, why do you think teenagers might need brains which work differently?

"I would there were no age between ten and three and twenty… For there is nothing in the between but getting wenches with child, wronging the ancientry, stealing, fighting." (Shakespeare, The Winter's Tale, Act III, Sc. iii)

The teenage years have long been seen as a unique and sometimes challenging period of life. For many years this was thought to be due to hormonal changes associated with adolescence or factors in society. However, with the development of non-invasive brain scans such as Magnetic Resonance Imaging (MRI) scans, scientists have discovered that teenagers have a unique brain, not an old child or a young adult brain, which accounts for many typical teenage behaviours. Interestingly, in line with Shakespeare's quote, this stage in the brain's development lasts from the onset of puberty (around ten) to the mid-twenties. However, what Shakespeare did not recognise was that it is an essential phase for children to grow into independent individuals adapted to flourish in the world around them.

The brain is arguably the most important organ in the body, which we are only just beginning to understand. It is a complex organ made up of around a hundred billion neurons (nerve cells). The function of these neurons is to pass and process information between each other. Neurons pass information to each other across synapses. These are the minute gaps between two neurons. Many neurons activate simultaneously and the brain can use many different routes to perform the same function. However, when a route is used frequently it becomes a lot stronger and this means that the brain can complete the task more quickly, requiring less effort. Frequently used pathways become covered by a fatty white substance called myelin. This insulates the pathway and prevents interference from other neural pathways. This process is called myelination and is necessary for a mature nervous system. Knowledge of how the brain works on a basic level is vital to understanding bigger questions about the brain and how it works in different parts of life.

Knowledge of how the brain works including research into brain development has taken off in the last 40 years, with the discovery of non-invasive scanning techniques. Magnetic resonance imaging (MRI) scans are one of the most common types of brain scans, using magnetic fields and radio waves to create detailed images of the patient's body without damaging or causing the patients any harm. MRI scans have allowed doctors and scientists to study brains whilst they are performing different tasks or living brains over long periods of time. This has enabled them to understand how and when the brain develops. Previous brain research was limited to corpses. Scientists used to think that people were born with all their neurons, brain development was complete by the age of three and at about the age of five the neurons would start to die and not be replaced. However thanks to MRIs we now know that this is not the case. New studies have proven that brains continue to develop well in to our lives with neurons continuing to grow meaning that people can always learn new skills. However there are periods of life where the brain growth is particularly rapid and one of these is adolescence.

MRI scans have shown that brain's rapid development during adolescence occurs through the processes of pruning, networking and myelination. There is a huge growth in the number of synapses during adolescence, but not all of these synapses are needed or used. The little used synapses are pruned away and the frequently used ones contribute to the development of new networks. These give young people alternative ways to do things. Whilst these networks are being developed, it can make tasks more laborious and tiring to perform. This contributes to the tiredness often seen in teenagers. It also increases the likelihood of errors being made due to faulty connections between neurons. The frequently used networks are then myelinated which

reduces errors and increases brain efficiency. This process occurs throughout the brain, but scans shown that it starts at the back (the section of the brain responsible for co-ordination and balance) and moves forward through the brain to the pre-frontal cortex in later adolescence.
The prefrontal cortex is a section of the brain responsible for problem solving and judgement including the control of emotions. When fully developed, the prefrontal cortex takes a similar role to the conductor of an orchestra, making sure the different sections all work together in harmony. It contributes significantly to personality development. Scans have shown that the pre-frontal cortex is not fully mature until a person is in their mid-twenties and the experiences they have in adolescence will determine how their pre-frontal cortex develops and so someone's personality and how they live their lives.

A crucial part of the prefrontal cortex's function is to create hypothetical what–ifs. This means the prefrontal cortex will create hypothetical situations to judge the outcomes and to test the danger. This prevents people from putting themselves in real life dangerous situations and instead just testing them out in their brains. For example, a teenager without a developed prefrontal cortex might go out and drink a lot without thinking about the consequences, just because it is fun. However, an adult with a fully developed pre-frontal cortex would not drink as much because they would think about the hangover the next morning and decide it would not be worth it.

During early adolescence, hormones fuel the development of the limbic system. The limbic system is the part of the brain which drives emotions and also seeks pleasure and reward. These changes occur with the onset of puberty (aged ten to twelve) to around the age of fifteen. This is dramatically earlier than the maturing of the pre-frontal cortex. This leaves around ten years of mismatch in adolescent brains with risk taking and novelty seeking behaviour being driven by a limbic system with a pre-frontal cortex that isn't mature enough to prevent these actions. This imbalance between two key areas of the brain leads to the unique features of the 'teenage brain'

So how does the teenage brain affect them? Studies have shown that compared to adults and children, teenagers show exaggerated responses to large rewards and very little responses for small rewards. During imaging studies (Powell, 2006 cited by Molly Edmonds how stuff works), scientists noticed that, when presented with different reward, teenagers showed exaggerated responses to larger rewards but practically no response to smaller rewards in comparison to children and adults. Examples of everyday typical teenage behaviour that demonstrate this would be teenagers' love of thrill seeking behaviour such as alcohol and substance abuse and difficulties with personal motivation to complete school work.

The teenage brain is a lot less efficient than an adult brain. It is using the side roads to get somewhere not the motorways. In a psychological study (B. Luna, cited in L. Sabbagh, 2007), subjects were told to either focus on flashing lights or ignore them. It was discovered that when trying to block a strong reflex and make a response, teenagers use a lot more of their pre-frontal cortex than adults did. In fact, teenager brains use the same amount of prefrontal cortex as when adult brains are performing much harder tasks. This leads to error when performing more difficult tasks. The difference in methods means that teenagers find tasks more tiring, they are more vulnerable in times of stress, are more impulsive and make more mistakes.

Not only are teenagers more likely to make mistakes, psychologists have shown they are much less likely to spot them. Scans have shown that when making decisions, teenagers use the back of their brain whereas adults tend to do most of their processing toward the front of the brain. One study (R. Monastersky, 2007 cited by Molly Edmonds how stuff works) showed that when using quick response of pushing buttons, adults noticed a blunder in fewer than 80 milliseconds whereas teenagers simply didn't notice any error at all.

Although we can look at the teenage brain as a single thing, it is continually and rapidly changing throughout adolescence. One study (S. Tapert, cited in L. Sabbagh, 2007) showed significant differences between the ways twelve- fourteen year olds solved the same task to the way fifteen to seventeen year olds did. This was due to the fact that they were at varying stages of the prefrontal cortex's development.

However, not everyone believes that the teenage brain is different to that of a child or an adult. They believe that the trouble we associate with adolescence is purely down to social influence and has nothing to do with the physical changes of the brain. They believe that adolescence is just a product of our post-industrial revolution society and say that teenage behaviour in western society is due to social influence and if teenagers grew up in a society where they were surrounded by more adults and fewer teenagers, then they would show barely any of the typical teenage behaviours and make better more thoughtful decisions. However, twin studies prove them wrong and show that even though society is a factor of the development of adolescents, biological factors impact teenagers much more. Twin studies (Scientific American, 2015) which follow twins who lead different lives and had different experiences, found that the twins still have the same pace of maturation of grey and white matter. There were more similarities in their development than similarities between people with similar lifestyle experiences. This suggests that teenage behaviour is biological more than social.

Sociologists have also noticed that risk taking happens in all cultures although they do agree that it occurs more in some than others. This could be due to what sort of behaviours are seen as risky. It happens to a lesser degree in societies where adults spend more time with children. This is thought to be because teenagers are fast learners and can learn good decision makers from the adults around them. This shows that social factors don't override biology.

Another argument for the importance of biological factors influencing teenage behaviour can be seen in animal studies (BBC, 2012). All mammals show elements of adolescent behaviour which shows that society isn't purely responsible for the way teenagers behave. For example, one study (B. Natterson- Horowitz and K. Bowers cited in; BBC, 2012) showed that sea otter parents try their best to prevent their teenage pups from venturing into the "triangle of death", an area of the ocean with sharp rocks, dangerous currents, no hiding spaces and plenty of great white sharks, yet adolescent males still venture into the dangerous area. No adult otters have been found in this area. This shows that humans aren't the only species to make poor decisions during adolescence. Another study (C. FitzGibbon cited in BBC, 2012) showed that young gazelles (Gazella Thomsoni) also make risky choices. They chose to chase and follow predators instead of running away when they detect a group of lions of cheetahs. This seems a very odd behaviour as it is extremely dangerous but scientists believe it is necessary for the success of the species as it gives the young gazelles a chance to learn more about their predators and how better to survive a predator attack. This shows that teenage risk taking is a vital behaviour to test boundaries and learn limits and grow up to be a successful adult.

The teenage brain is different to that of an adult or child, but why? Teenagers need a different brain so they can learn, have new relationships and ultimately fly the nest. In order to do these things teenagers need to have new experiences and take more risks. The physical makeup of the brain means that this is easy and comes naturally to adolescents.

One of the most important purposes of the teenage years is to learn, in school and at home. During adolescence, teens will complete school exams and attend university or college or follow other career choices. The teenage brain has to be equipped to retain vast amounts of knowledge and learn a huge array of new skills. Every individual follows a different path and so teenagers have to be able to keep their options open so they don't have to choose what they will do for the rest of their lives at too early a stage. The plasticity of the brain through the process of pruning and myelination makes this all accomplishable and helps teenagers learn very fast and adapt to their environment easily. This flexibility of the brain can be seen to be very effective in the way that teenagers have been able to embrace modern technology and use it in a way the older generation has not been able to.

Another purpose of adolescence is to make new relationships outside the family group. This increases genetic variety and prevents difficulties caused by inbreeding. During the teenage years, people tend to break the strong, intimate ties with their parents and start to make new ties with peers instead. Studies (J. Zeman, psychology Jrank) have shown that Year 9 students, boys in particular, have been reported to hide and control their emotions around their parents much more than when they were younger. They are much more likely to share with their peers than their families and this opens opportunities for new relationships and potentially new mates. Teenage brains are wired to find social relationships highly rewarding and so seek out new friendships. As they become older and their brain develops further, they become able to navigate complicated social relationships, tell friends from foe, find the right group for protection and to carry out the arguably most important function of adolescence- to find a mate. It has also been argued that their challenging behaviour can lead to their parents pushing them out into the wider world.

Another crucial part of adolescence is to become independent and move away from the family home. In order to fly the nest, teenagers need to be motivated to take risks to learn their limits and leave the security of the family home. Just like in the gazelle study, risk taking in teenage years with an adult nearby leads to more competent adults. Unfortunately some of the dangers in modern society mean that teenage risk taking can be dangerous. The easy availability of drugs and alcohol and fast cars can lead to high levels of teenage addiction and death.

In conclusion, adolescence is a vital part of human development in order for children to develop into well-rounded individuals who can thrive in social and professional situations. Recent discoveries have shown that typical teenage behaviour is not due to hormones, as scientists once thought, but due to the development of the brain. This special period is seen in all mammals, but is most pronounced in humans due to their highly developed frontal cortex. The period is characterised by rapid learning and this has meant that humans been able to evolve into a highly adaptable species which is successful in a wide range of places and time periods. The risk taking element of adolescence can lead to sound adult judgement but in modern society can also lead to addiction and mental illness. Knowledge of the brain is developing all the time and the focus of research is now how to use this knowledge to ensure the teenage years are positive ones for everybody.

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What evidence do we have that teenagers' brains are different from adults' brains? Why do you think teenagers might need brains which work differently?

Teenagers may be stereotyped as the rowdy, stubborn and the most disobedient age cohort, but is this necessarily due to puberty and hormones or is it perhaps caused by the immaturity of their neural anatomy and psychological development?

With advanced technology scientists are able to delve deeper into the development of the brain as it progresses through adolescent years to investigate brain function, development and behaviour. Through extensive research, there have been many surprises showing us that the brain is not fully developed as an adult till the early 20's. One of the first interesting discoveries was that sections of the teenage brain are not connected fully until they have matured. Scientists say that the age of adolescence is one of optimum physical strength, health and mental capacity though this can also prove to be a dangerous age. Teenagers lack many nerve connections that join the frontal lobe to the rest of the brain, which evidently affects their ability to think ahead as the mortality rates of 15 to 19 year olds are about six times that of 10 to 14 year olds. This is also similar in studies of crime rates and alcohol abuse as they are significantly higher among teenagers than any other age range. Parents have also wondered what urges their teenage children to act impulsively and make irrational decisions. Neurological discoveries show that perhaps teenagers are unable to prevent it.

The brain is made up of grey and white matter. The grey matter stores information and the white forms connections between parts of our brain. Even though our grey matter is developed at the age of 11 or 12, our white matter continues to mature until our early twenties. As a teenager this affects the brains ability to process information the way adults do which controls our attention span, impulses and motivation. This can make learning and exploring new experiences engaging and interesting for teens. However, there is also a negative to teenage curiosity, this makes teenagers more likely to adopt addictions, yet for adults the brain chemistry shows us that pleasurable addictions must return to a sense of maturity faster which makes forming habits more difficult. This grey matter increases in size resulting in an increase in synaptic connections between nerve cells. During puberty, a process begins at the age of 11 in which connections that are not reinforced begin to wither. This continues into the early 20's particularly in the prefrontal cortex which is the area that stimulates planning, reasoning, judgement and impulse control. Coating the brain is a fatty layer called the myelin sheath which protects the nerves and axons in the brain and makes connections faster. Though in a teenage brain the maturation of the sheath continues which tends to make them grow into a more intelligent and responsible person. This efficiency to conduct electrical signals continues into adulthood and is called myelination and the process is only complete until a maximum age of 45.

Another strong contrast between adults and teenage brains are their response to emotion and facial expressions. A test administered at the McLean Hospital in Massachusetts discovered that teenagers interpreted emotions very differently to adults due to their ability to connect and process information. After being shown a picture of a man the adults recognised his emotion as fear unlike the teens who interpreted the emotion as anger. Also in a similar recent study it showed that teens made 15% more mistakes when attempting to stop themselves from pressing a button when they saw a threatening facial expression.

This can be supported by the evidence that an old primitive part of the brain called the amygdala which controls primitive impulses, aggression, anger and fear is heavily relied on by adolescents. This research was discussed in the Supreme Court over the death penalty of Christopher Simmons, who at the age of 17, abducted and murdered 46 year old Shirley Crook. The American Psychiatric Association have filed a brief suggesting that older adolescents may not have the ability to exercise control on impulses due to premature brain development connected to their amygdala. With magnetic resonance imaging, it may be possible to consider whether not to execute a convicted juvenile for violent crimes due to aberrant prefrontal cortical activity.

Indeed, as previously said, risk-taking is an indelible part of the teenage years due to heightened sensitivity, high levels of dopamine and for younger males an increasing amount of testosterone which may also play a factor to the teenager's conspicuous reckless behaviour. However a study shows that teens are more self-conscious than younger children and adults when with their peers - a result of social expectations. This was tested as older adolescents had a 50% increase in the chance of being involved in reckless behaviour with peers. These high levels of dopamine and reproductive hormones released from the pituitary gland in the hypothalamus, the part of the brain the controls the internal environment of the body, shows not only a physical change but a social change. As with reproductive hormones during puberty they have a complex effect on the brain's ability to understand emotion resulting in a change in behaviour.

In addition the brain of an adolescent can also have intellectual advantages in learning. The brain capacity of a person to learn and memorise is at its optimum level during the teenage years. This is due to fibres that connect nerve cells which are wrapped in a protein which causes an increase in the speed of electrical signals. Research is still finding answers to prove that increases in connectivity during puberty is related to growth in intellectual capacity such a memory and reading skills.

Interestingly, research suggests that during adolescence the brain changes its circadian rhythm of sleep, leading to the tendency to stay awake at night. Obvious effects such a sleep deprivation and fatigue leads to difficulty in maintaining focus academically however it can also lead to irritability and depression. Studies of not only teenagers but young children also lead to impulsive behaviour which researchers have found could lead to delinquency in later years. According to oneirological scientists – the study of dreams in relation to the brain, believe nine and a half hours of sleep is essential for all children and young adults for stable emotional and physical health.

Parents play a crucial role during the adolescent years, and the influence of parents can positively impact the developing brain and possibly alter the way their teenage children mature. Since their prefrontal cortex is immature, adolescents will benefit from the wisdom and guidance of their parents in making decisions and learning from their mistakes to progress in their own lives. Stress, family structure, and communication can help minimize exposure to delinquent behaviours which will protect the adolescent, not just during the teen years, but also long term. Parents can even take advantage of the need for excitement by seeking positive experiences for adolescents. Parents can challenge their teen's academic capability to find excitement in learning new things which will in turn benefit their education. Teens that feel adrenaline and excitement through athletics could possibly use that ability physically to learn a new sport or activity. These challenges produce the same sort of dopamine levels that teens receive from things that are risky, dangerous and sometimes illegal. This is a safe and more beneficial way of receiving adrenaline from new experiences for parents with teenagers.

In addition, it is not surprising that the behaviour of adolescents would be a study in change, since the brain is continually changing during puberty up until adulthood and for some adults the maturation of the brain still continues. Scientists strongly emphasise that the fact that the teenage brain is still in its transition, however this does not mean that somehow all teenagers are notoriously reckless without the capability for a reasoned judgement. It is different from both a child's and an adult's in ways that may equip teenagers to make the transition from dependence to independence. This transition may be an advantage intellectually yet it can be a lethal and a hazardous period of one's life. The capacity for learning at this age, an expanding social life, and a taste for exploration and limit may, to some extent, be reflections of age-related biology as well as hormonal changes in our anatomy of the brain during this stage.

Furthermore, understanding the changes taking place in the brain at this age presents an opportunity to intervene and prevent the early signs of mental illnesses, which is a fantastic advance in neurological science. Research findings on the brain may also serve to help adults understand the importance of creating an environment in which teens can explore and experiment while helping them avoid behaviour that is destructive to themselves and others.

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What evidence do we have that teenagers' brains are different from adults' brains? Briefly, why do you think teenagers might need brains which work differently?

The expansion and development of modern technology like Magnetic Resonance Imaging, or MRI, has enabled scientists to look more closely at the brain and follow its growth from birth to adulthood. They have used this information to study the connections between brain function, development, and behavior, leading to some unexpected discoveries. Studies have shown how the brain finishes developing much later than previously suspected meaning the brain of a teenager is changing and working in a different way to an adult's.

The anatomy of a teenager's brain is different to either a child or adult brain as there are some large changes throughout adolescence, with some important stages of development occurring. This contributes to why teenagers can behave in such unpredictable ways compared to an adult as the adult brain has finished maturing therefore having a more stable and noticeably different structure. According to the US National Institute of Mental Health, the main reason that scientists have studied the brain as it develops is due to mental illnesses that are increasingly viewed by scientists as development disorders that are first made in the process involved in how the brain matures.

Studies involving brain scans of children as they grew up from early childhood to the age of 20, have shown the large amount of changes that occur in the teenage brain. These scans revealed that the volume of gray matter has some surprisingly late changes. The grey matter forms the thin, folding outer layer or cortex of the brain which is where the process of thought and memory are based. The volume of grey matter in the cortex increases and the declines through childhood, however, a decline in volume is normal at this age as it is a necessary part of maturation.

However, in these studies the detail of the changes in volume on scans are not completely clear. That said, the results showed that the brain maturation timeline goes into adolescence and early adulthood. The brain images proved that the volume of grey matter does not resemble that of an adult until the early twenties. Also, the brain scans suggest that different parts of the cortex develop at different rates and so the areas involved in the more basic functions mature first.

Grey matter is made up of three main things: the cell bodies of neurons, the nerve fibers that project from them, and support cells. In the early growth of the brain, one feature is the early forming of synapses, the connections between brain cells or neurons. This is then followed by the pruning of synapses as the brain matures and grows. Synapses are the relays over which neurons communicate with each other and are the basis of the working circuitry of the brain. At birth, these connections are even more numerous than in adulthood; then in the first months of life the synapses multiply rapidly. To show the complexity of the brain: a cube of brain matter ($1mm^3$) can contain from 35 to 70 million neurons and an estimated 500 billion synapses.

There are some key changes that occur in the teenage brain giving it some very different features to that of an adult. The loss of synapses as a child matures is believed, by scientists, to be part of the process by which the brain becomes more efficient. This causes the decrease in grey matter in prefrontal regions of the brain, occurring mainly during pre-adolescence and early adolescence - the time when major improvements in basic cognitive abilities and logical reasoning are seen.

Evidence that the adult brain is different to a teenage brain is shown quite clearly here. The pruning of synapses in the development stages of the brain means that the teenage brain will have a larger amount of synapses, and therefore a larger amount of grey matter than an adult brain.

An increase in white matter in the prefrontal cortex is also seen during adolescence, largely being the result of myelination – the process where nerve fibers become covered in a myelin, a fatty substance that improves the efficiency of brain circuits. However, this change in the brain continues into late adolescence and early childhood finishing much later than the pruning of synapses in the prefrontal areas. According to Laurence Steinberg, this is because more efficient neural connections within the prefrontal cortex are important for higher-order cognitive functions like planning ahead, weighing risks and rewards, and making complicated decisions that are regulated by multiple prefrontal areas working together.

A third significant change in the teenage brain is the increase in the strength of connections between the prefrontal cortex and the limbic system. Being particularly important for emotion regulation, this anatomical change is enabled by more connections between regions that are important in the processing of emotional information and for regions involved in self-control. These connections are being strengthened well into late adolescence allowing different brain systems to communicate with each other more effectively. Evidence of comparing a young teenager's brain with a young adult brain shows a much more extensive network of cables connecting brain regions.

Teenage years not only provide great change in the structure of the brain, but also important changes in how the brain works. This was proven in studies using functional magnetic resonance imaging or fMRI. These imaging studies reveal that there is a strengthening of activity in brain systems relating to self-regulation over the course of adolescence and early adulthood. In tasks that involve self-control, the adult brain uses a wider network of brain regions than an adolescent brain does. The adult brain largely makes self-control easier by distributing the work from the task across multiple areas of the brain instead of overloading a fewer number of regions. Therefore the neuroscientific evidence provides added support to behavioral evidence explaining why teenagers can behave in different ways and with less self-control than adults.

The US National Institute of Mental Health quotes, "The capacity of a person to learn will never be greater than during adolescence. At the same time, behavioral tests, sometimes combined with functional brain imaging, suggest differences in how adolescents and adults carry out mental tasks. Adolescents and adults seem to engage different parts of the brain to different extents during tests requiring calculation and impulse control, or in reaction to emotional content." This information helps us to understand the differences in adult and teenage brains and also the way they work and develop. This gives further evidence to other studies that look at similar aspects of how the brain works.

As the brain matures throughout adolescence, there is also some development in the way the brain responds to rewards. A study where a brain scan was taken during a task in which individuals were shown rewarding stimuli, revealed that, usually, adolescents' reward centres are activated more than in children or adults. Increased sensitivity to anticipated rewards leads teenagers to become engaged in, sometimes risky, actions when there is potential for a higher degree of pleasure from the reward. This supports the reasons why adolescents are motivated to do things like take drugs or drink large amounts of alcohol. These age-related changes shape how much different parts of the brain are activated in response to experience, and in terms of behavior, the urgency and intensity of emotional reactions.

Jason Chein and Laurence Steinberg have led a study in their laboratory giving evidence that this hypersensitivity to reward is particularly distinct when teenagers are among their peers or friends. Chein and Steinberg believe that this helps explain why adolescent risk taking occurs more in groups than in individuals. Studies like this give evidence why the teenage brain is more willing to take risky actions than adult brains.

A different change in the function of the brain over the course of the teenage years includes increases in the simultaneous involvement of multiple brain regions when responding to arousing stimuli, for example pictures of angry or terrified faces. In the teenage brain, there is less communication between the brain systems that are needed in rational decision making and the ones that regulate emotional arousal. During the teenage years of the brain, very strong feelings are less likely to be controlled or modulated by the brain regions connected to controlling impulses, planning ahead, and comparing the costs and benefits of different courses of action. This gives evidence to why a teenage brain is more susceptible to peer pressure than an adult brain because as individuals mature, they become better at controlling an impulse occurs because of arousal from their friends or peers.

However, this is may not be entirely correct in all teenagers and adults as the way individuals react to things like arousing or reward based stimuli is also dependent on many other factors like the environment they are in and the people that surround them. It is also unclear how many brain scans of different individuals were taken in this study causing possibly less reliable results.
In May 2013 the NSPN (scientists from the University of Cambridge and University College London) led a research project called the "U-Change" study that looked into what happened to the brain as young people mature. According to the University of Cambridge in 2013, the study plans to use brain scans, questionnaires and genetic testing on 300 people between 14 and 24 years old to 'improve the understanding of how different parts of the brain develop'. The lead researcher of the project from the University of Cambridge, Professor Ed Bullmore, said "It seems very likely that the major cognitive, emotional and behavioural changes of adolescence will turn out to be related to the alterations that occur in brain networks during this period."

Being the first study of its kind to use both conventional MRI and fMRI, U-change allows researchers to measure brain function in the same people. This is because the conventional MRI can be used to examine normal youth brain development by taking scans over a period of several years while fMRI, a type of brain scan, enables scientists to see blood flow which represents brain activity. Furthermore, volunteers will answer questionnaires to assess socio-demographics, mental well-being, environment, and more, as well as doing tests to assess their impulsive and risk-taking behaviour.

Professor Bullmore believes that developments in the brain as adolescents mature eventually enable young adults to bring their impulsive behaviour under control. "I think we are going to find that decision-making processes in the younger teenagers are driven by short-term considerations, immediate emotional states and immediate past history of what was rewarding." This prediction agrees with the results from the study done by Chain and Steinberg on the hypersensitivity of reward in teenage brains. However, this study is likely to look into more detail about the way the brain reacts as there are a higher number of methods being used. Chain and Steinberg only looked at brain scans in a very direct area of the working of the brain giving it less results to compare or link with other studies.

A similar study is the Adolescent Brain Cognitive Development (ABCD) study, run by the US National Institute of Health, which is looking closely at the teenage brain and its development through the changing years. Approximately 10,000 children from ages 9-10 will join the study and be followed into early adulthood. Integrating structural and functional brain imaging with genetics, neuropsychological, behavioral, and other health assessments, the ABCD Study will increase understanding of the many factors that can enhance or disrupt a young person's life.

This study has included many more people over a wider age group than the U-Change study making it more reliable and informative. The U-Change study is lacking in numbers and only has a ten years of following individuals to gain evidence. Comparing the two studies shows the improvements needed in numbers for the U-Change project. Additionally, the ABCD study is taking people from a very large range of areas across the US trying to keep a balanced outcome. Nevertheless, both studies can be used to give evidential information on how teenage brains develop and the differences they have with adult brains.

Using all the evidence that has been supplied by varies studies and research projects, I think teenagers undergo so many changes in both brain and body that would require a brain which works differently. The development in the structure of the brain from a teenager to an adult is extensive but what is really key is the way it works. I think there are many reasons why teenagers might need brains which work differently including the different ways in which our brain learns at different stages of our lives.

Research in studies has shown that during adolescence the brain is at its best to learn and process new information. Teenagers going to school need this quality to help them work and learn the information they are taught. Exams also feature largely during the teenage years meaning there is a need for a brain that finds learning and processing easier. During adulthood there is less of a need for this skill as we have got to a point where the brain has learned the vital information and then can learn more throughout our lives.

The responses of the brain and how it works in that aspect, I think, is due to changes during puberty. Puberty leads to many changes in the body and the brain is likely to need to be able to deal with that by working in a different way to an adults. Adolescents are at a stage in their life when they become more independent and less dependent on the people around them. The brain will need to work differently to enable the process to happen.

To conclude, the teenage brain is a highly technical organ that goes through much development to get to an adult brain. I have written about the changes that occur during the teenage years and the differences that there are to adults' brains. Evidence has proved how there are some surprisingly unalike features that are shown between the two brains and as technology continues to advance, so will the evidence. The questions that could be asked for future exploration and research could be based on "how much does the environment or the people that surround an individual affect the growth of the brain?" or "how we can use the evidence already supplied to train our brains to speed up the maturation process to give us a more developed brain earlier on in our lives?". Teenagers' brains are unlike either a child's or an adult's and I believe they could lead to some big discoveries in the future.

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What evidence do we have that teenagers' brains are different from adults' brains? Why do you think teenagers might need brains which work differently?

"Scientists used to think that brain development was pretty complete by age ten, that a teenage brain was just an adult brain with fewer miles on it."
-Francis Jensen, neurologist, Boston Children's Hospital

Today, in 2016, how do we know that a teenager's brain is not just a dumber version of an adult brain? In this essay I will be discussing the evidence that psychologists have found that proves how different the adult and teenage brain are. There are both physical and emotional differences between the two.

To start, the brain is made up of lots of different parts; the frontal lobe, the parietal lobe, the temporal lobe, the occipital lobe, the brainstem and the cerebellum. The frontal lobe has the most significant differences in the adult brain compared to the teenagers' brain. The frontal lobe controls planning, problem solving, organising, memory, impulse control, decision making, selective attention and controls our behaviour and emotions. The teenage brain is going through a process called neuromaturation. Neuromaturation is the way that the brain matures, and we now know that the brain is not fully matured until someone is in their early to mid twenties. Subsequently, adults can think more efficiently than teenagers and have better control over their impulses and emotions. However, teenagers' brains aren't half asleep or under developed; the adolescent mind is going through massive physical and emotional changes.

Until relatively recently, many children would stop going to school when they were 14 or even younger. There were no laws to keep them in school for longer, and instead they were expected to go out to work; in many countries this is still the case. This is a shame because the brain continues developing until the early twenties and it is during adolescence that the synapses in the brain are strengthened. The word 'synapse' comes from the ancient Greek meaning 'conjunction' and in the brain, synapses are the pathways that allow impulses to travel from the brain to the cells. If certain synapses are not used in the teen years, then they stop working altogether. "You can think of it a bit like pruning a rose bush," said Professor Sarah Jayne Blakemore in a talk about brain development. "You take away the weaker branches so that the remaining, important branches can grow stronger." If a teen stopped doing a certain activity, for example music or maths, it would be very hard for them to pick it up again later in life. It is like the brain is pruning away all of the skills that you don't use so that the ones that you do use can be done more efficiently.

If a person stopped using their brains when they were still in their youth, rarely used neural connections would stop being used completely and so lots of future potential could be lost. In time, teenagers get increasingly better at doing things that come with adulthood, such as impulse control, attention, and motivation, but this doesn't happen until someone has reached their mid-twenties.

In the adult brain, the frontal lobe is fully developed and they can therefore think ahead when they make decisions. However, teenagers lack many of these crucial nerve connections that tie the frontal lobe to the rest of the brain, limiting their ability to think ahead. Adults and teens natural behaviour is naturally very different. If a teenager is speeding in a car, they would not necessarily think about the consequences of their actions; the fine they would get charged if they were caught or what would happen if a child suddenly ran out into the road and they hit them. On the other and, an adults' brain is more developed and is has a stronger ability to think about the near future and the consequences of their actions, so they would be less likely to exceed the speed limit. With this example, however, it may seem that experience would be the thing making the adult drive more safely. If an adult has got caught speeding, the likeliness is that they would not do it again, but even if they have never broken the speed limit, their brain would be able to think of the consequences and therefore not do it. The teenager's brain does not have this ability, and this is what will tempt them to speed. In calm situations, adolescence can rationalise almost as well as adults. But stress can hijack their decisions and make it a "hot cognition" as Ron Dahl, a paediatrician and child psychologist calls it.

Continuing on the topic of stress, stress affects teens more than it does to adults. "Teenagers experience stress as more stressful," study researcher Adriana Galván, at the University of California, Los Angeles, said on an online publication. "If that stress is interfering with their decision making, it's really important to understand the neural mechanism that's underlying this connection between high levels of stress and poor decision making." This means that stress affects how teen make decisions in a negative way; if they are highly stressed, they are more likely to make bad decisions. Therefore, if an adolescent is stressed about school and an adult is stressed about work, the teen is more likely to get themselves in a bad situation because of the neural mechanisms in their brains.

There is a physical reason behind this. The brain is made up of white and grey matter; the grey stores information whilst the white makes connections with different parts of the brain. Most people will admit that the teenage years are the hardest and that they are full of stress. Stress marks the whole brain, but it especially marks the white matter. In an experiment on a young rhesus monkey and its relationship with its mother, researchers investigated the long-term impact of parental mistreatment on offspring. The young monkey's boost in stress hormones most likely led to negative long-term effects on white matter. In turn, the changes in white matter are linked with social aggression, poor visual processing, and emotional regulation. However, once the white matter is developed, stress doesn't affect it as much as it did in the teen years. If adults did not have a massively stressful youth, they should have more healthy brains and minds than people who were under constant stress or abuse.

Another crucial reason why adults and teenagers are so different is that teenagers are literally missing a part of their brain that makes them act like adults. The adult brain is covered in a thick coating of whit fat called myelin, which stretches over and protects the nerves in the brain. The myelin makes connections in the brain faster. And because adults have this and teens do not, the thinking process and all other processes are much faster and more efficient than they are in the teens' brain. I think that this is one of the most important pieces of evidence we have to prove that teens' and adults' brains are different because as the myelin develops, teenagers are able to start acting like more responsible adults; teenagers are not 'lazy' or 'slow'; they just have less myelin in the chemical make-up of their brain.

Most people think that when teenagers sleep late in the mornings, it is just because they are being lazy. However, sleep is actually crucial to teenagers, as major growth and development happens when they are asleep. Consequently, as adults' brains don't develop in their sleep anymore, teens do actually need more sleep. Sleep patterns are controlled by cortisol (a hormone that helps us wake up,) and melatonin, (a hormone that helps us go to sleep.) In adults' brains, the melatonin can be activated by 10pm, but with teenagers, it sometimes takes until 1am. Consequently, as most schools start early in the morning, adolescents end up getting very little sleep, which makes them significantly more irritable and impulsive.

A teenager's wish to 'stay up late' is caused by the chemical effects of puberty, but there's something else going on too. It's also often fuelled by the want to stay on social media for a long time. It is natural for a teen to want to be constantly surrounded by their friends, and the reason for this actually dates back to thousands of years ago. It was far safer for early man to be surrounded by other people than be on your own, because then you were protected from predators. Therefore, in some ways it is human nature and survival instincts for teens to stick together and want to be around each other all the time.

It is very common for teenagers to feel ‘misunderstood’ and adults often claim not to be able to understand teenagers’ actions. ‘Why did you do that?’ ‘What were you thinking?’ are questions and accusations that teenagers often hear as a result of their actions. Psychologists have found that the physical differences between the adult and teenage brains lead them to interpret situations differently from each other. In an experiment at McLean Hospital, some teenagers and adults were asked to look at pictures of other peoples’ facial expressions, and interpret the emotions on their faces. After the conclusions had been drawn, it was found that teenagers and adults read emotion very differently. For example, the facial expression that was recognised as fear by adults was recognised as anger for the teenagers. This is because the adults and the teenagers were using different parts of their brains to process the information, so the result was different. The teens mostly used the amygdala, a small almond shaped part that makes instinctual or "gut" reactions, while the adults relied on the frontal cortex, which controls reason and planning. The main reason for this is that the teens’ frontal cortex is less developed; they will have a more of an emotional response. The part of the brain that has more of a ‘gut feeling’ will respond much more than the adult brain will. Scientists think that that is due to the fact that the frontal region is interacting with teens and adults differently. The result is that world can look very different through an adult’s eyes than through the eyes of a teenager.

Teenagers are often put into a stereo type of being foolish and making the wrong decisions and choices. Now psychologists have discovered that teenagers have a much higher chance of getting addicted to things, whether they are good or bad. Evidently, if a teen starts having a drug before the age of 18, they have a 25% of getting addicted, whilst if they start after the age of 21, they only have a 4% chance of getting addicted. As a controlled experiment, a team of scientists injected low doses of cocaine into young and adult mice in a certain environment, and were given salty water in another environment. With the young mice, it only took a small dose of cocaine for them to go back to the environment where they first got it, but with the adult mice, it took much higher doses for them to prefer the environment with the drug. This implies it is wired into all teens’ brains to become addicted much faster than adults. This is more likely to be a negative trait because it means that a teen is far more likely to become addicted to drugs or alcohol than adults, and this could affect their brain and their health for the rest of their lives.

The adolescent teen brain also seeks rewarding activities, even if it involves taking risks. Statistics show that teens are five times more likely to be in a car accident when with friends. A study was done, where teens and adults were asked to play a game where they had to drive to a place in a short amount of time for a reward. There was an amber light where the participants were meant to stop. Taking the risk of going through the amber light, although it could cause to crash with another vehicle, would get them to the finishing line quicker. Each participant played the game alone whilst being watched by friends, and it was found that only the teens took the risks while their friends were watching, whilst none of the adults did. This is because there is a part of teenagers’ brains that seeks rewarding activity, for example the pride that their friends would give them if they did something “cool” or out of the ordinary.

There are many reasons why teenagers might need brains which work differently. As discussed, the brain develops while teens sleep; the teenage brain is chemically wired to require more sleep. Teenage brains don’t suddenly ‘switch on’ in adulthood. They develop, change and eventually decide what the finished product adult brain will look like and how it will think and react. I think that teens may need different brains so that their brain can manage and cope with all of this change that it is going through efficiently.

Additionally, psychologists know that teenagers seek acceptance and approval from others and often enjoy being in large groups as opposed to being alone. Adolescents learn how to collaborate through socialising and this is crucial to the development of their brains. Also, as the human race evolved it was much safer for humans to gather in groups; they would be safer from predators and could find food with others more easily, so this need to be with others had a clear evolutionary advantage. When teens grow into adults, they don't feel the need to be with others constantly, which is another reason why they may need brains which work differently.

So teenagers need a lot of sleep, they enjoy socialising and having people around them, they are addictive by nature, they interpret emotions differently and they often feel high levels of stress. This all happens because their brains are going through massive physical changes.

In conclusion, I now know that teenagers do not have dumb, under formed brains; they have brains that are constantly taking in information, processing emotion and deciding which pathways to pursue and which to prune. Albert Einstein said,

"A person who never made a mistake never tried something new."

I think that the teenage brain is making mistakes and trying new things all the time and youth is definitely the right time to do it.

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What evidence do we have that teenagers' brains are different from adults' brains? Briefly, why do you think teenagers might need brains which work differently?

In everyday life, the brain is often overlooked as something we have, and that we need, but not that we need concern ourselves with in terms of exactly how it works. The basics of the brain are easily understood: we know, for example, that the brain sits atop our body protected by the skull and that it is the hub of information for our entire bodies. However, unlike most of the organs in the human body, the brain is still, for the most part, a mystery to scientists today. If you really sit back and think, contemplate for a second what the brain actually is, you realise that within our brains is everything that we are. It contains our memories, our morals and our emotions; our deepest loves and darkest hatreds are captured in the one-and-a-half-kilogram organ behind our eyes. But if the brain is everything that we are, and we become who we are as we move through our lives, then the brain must therefore develop gradually, with us. From childhood to old age, we, and our brains, develop, but no period in our lives is so important to the creation of who we are as our adolescence. This essay endeavours to delve into this tumultuous time in every human being's life, to analyse how and why the brain is so different in our teenage years than at any other time in our lives, and ultimately explore why a teenager's brain needs to be so unlike that of an adult.

To begin, the media often pushes the view that many teenagers are the victim of addictions, accidental injury, or in some cases, death, as they seem to seek out new and perhaps unsafe experiences. This, however, is not down to complete stupidity, but instead due to the chemicals within the brain during adolescence. Dopamine is a neurotransmitter, which, when released, gives one the feeling of being alive – it makes us feel happy and contented. During adolescence, baseline levels of dopamine drop, and as a result, teenagers feel bored when not being stimulated. However, when we are excited, the teenage brain releases much larger quantities of dopamine than at any other time in our lives – giving us an overwhelming feeling of joy, which, as we seek this feeling out, drives us towards new experiences. This drive to find something new means that our brain places more emphasis on the potential benefits of an activity, rather than the downside, and this is known as hyper-rational thinking – our decisions are unbalanced, unlike that of an adult with more regular dopamine levels, who would take in all aspects of the decision before making it (Siegel, 2016). This information on dopamine and hyper-rational thinking has been validated by many scientists and psychologists, such as the aforementioned Siegel, and recounted at various events first hand, and therefore I consider it to be reliable. Overall, teenagers are more prone to being the victim of a dangerous situation as their brains do not allow them to perceive the hazard ahead of them, blinded by the potential of a dopamine release and the feeling of happiness.

Leading on from this, the second difference between the teenage and adult brain to consider is their different response to rewards. During adolescence, the teenage brain is much more responsive to rewards than it is in later life, and this originates in a region of the brain known as the striatum, which is where dopamine is secreted from. Experiments carried out by Dr Adriana Galván produced results which showed that when subjects were rewarded with sugar-water during a Functional Magnetic Resonance Imaging (FMRI) scan, all age groups responded positively, but none so much as the teenagers. Teenagers enjoyed the reward much more than adults, and this suggested that during adolescence, the striatum is far more active than in adulthood, and therefore the teenage brain is considerably more responsive to rewards. Furthermore, the tests showed that those who had the greatest response in their striatum also said they would like the sugar-water more before the test began, demonstrating that when the brain is excited by something, it also makes us think it is better for us, biasing our decisions in the future (Galván, 2016). However, this experiment is not entirely conclusive, as it only used a small sample of people, and as a result, it would need to be replicated multiple times with a larger group to be considered valid. To summarise, a teenager's striatum is far more active than that of an adult, and as a result, teenagers possess a much larger response to rewards.

Staying in the region of decision making, the teenage brain also differs from that of an adult in terms of their prefrontal cortex (PFC). The PFC is the area at the front of the brain responsible for considering the consequences of one's actions and decisions, and regulating social behaviour. Teenagers are known for making impulsive choices and decisions that may affect them negatively later on, simply because they have not looked to the future before acting. This is not, however, simply due to teenagers not caring for the consequences of their actions, but because during adolescence, the PFC has not yet fully developed and matured, as this process takes place from the back of the brain to the front, as demonstrated by various in-depth brain scans. Excluding those decisions imbalanced by the appeal of dopamine or rewards, teenagers often take the wrong path as they are simply not equipped with the relevant regions of the brain yet. Put simply, the PFC is constantly forming and evolving during adolescence, and as a result, it is totally unreliable, causing a teenager's decisions to be unreliable too.

From here we look to a new area of growing into an adult– drifting away from our caregiver, and looking towards our peers. It is in the very nature of young mammals to form attachments to older figures, such as your mother and father, as they provide what Daniel Siegel refers to as the four S's – you are seen, safe, soothed and secure. But as we grow up, we drift away from our parents and look towards our fellow adolescents. This process isn't simply rebelling for the sake of it, but instead is an instinctual feeling, hardwired into our very DNA by millions of years of evolution. In the wild, when a mammal leaves its parents to become an adult, if it has not established a peer group to turn to for protection, death is inevitable. As a result of this, during our own teenage years, we feel it absolutely imperative to implant ourselves into a social group of some kind, as at the back our minds, we feel we cannot survive without one. This makes adults very different from teenagers, as they no longer feel this life-or-death instinct towards socialising. When a teen approaches their parent stating that they need to attend a particular social gathering, they say this not to exaggerate, but because deep down, they feel they may be rejected if they don't fit in (Siegel, 2016).

However, it is clear that evolution is not the only cause for a teenager feeling they need something – vanity and the like may also play a part, and as a result, this information is not totally trustworthy, as it seems not to take other factors into account. To sum up, another way in which the brains of teenagers and adults are different is their need for social acceptance – millions of years of evolution dictate to teenagers that they must find a peer group to survive, while this attitude towards others has faded by adulthood.

The approximate decade of adolescence is often associated with grumpiness, but this is not simply the result of the often scapegoated 'hormones', but of perhaps another more understandable reason – sleep deprivation. In terms of the chemistry of the brain, we are woken up in the morning by the production of cortisol, and are encouraged to sleep at night by the production of another chemical, melatonin. This is where the difference between teenagers and adults comes into play. In adults, melatonin production usually begins at around 10pm, while in teenagers this doesn't occur until much later, around 1am. As a result of this, the body's natural clock is pushed back during adolescence, with teens struggling to go to sleep at night and to rise in the morning. However, this is not completely reliable information, and cannot be taken as true fact in all cases – often teenagers will use devices late into the night, the light from which tricks the brain into thinking it's still light outside, and causes it to suspend melatonin production further (Green, 2016). In conclusion, the teenage brain is different from that of an adult in terms of sleep patterns, as in teenagers, melatonin is produced much later in the day than in adults.

The final factor which will be mentioned in this essay in terms of how a teenage brain differs from that of an adult is the way they respond to their surroundings. As aforementioned, in adults, much of the decision-making and logical thinking occurs in the PFC, but this is not always the case in teenagers. Deborah Yurgelun-Todd of McLean Hospital, Massachusetts, has conducted some experiments which subjected both adolescents and adults to images of facial expressions while hooked up to an MRI scanner. When shown a picture of a woman showcasing fear, 100% of adults recognised this emotion correctly, while only around half of the teenagers identified it right, saying she was shocked, sad, or angry. From the scans, Yurgelun-Todd deduced that the reason for this was that the adolescent's response, instead of coming from the PFC, originated in a lower part of the brain, known as the amygdala – a more emotional region responsible for gut reactions. From this, the scientists at McClean Hospital were able to understand that adolescents and adults respond very differently to their surroundings, as they use very different parts of their brain to do so. Applying these findings to real life, while many adults feel that teenagers aren't listening to their instructions, they may in fact be actually comprehending what is being said or shown to them completely differently. Adolescents cannot possibly always see eye to eye with adults, not because of stubbornness, but because the chemistry of their brains does not allow them to view the interaction in the same way. However, it must be mentioned that this source of information is not entirely reliable, as admitted by the scientist herself in an interview with PBS. The experiment was only a pilot study, and therefore only used a small group of people – it cannot possibly be considered representative of the entire human population, and therefore the experiment doesn't have high population validity. (Yurgelun-Todd, 2016).

After covering exactly how and why biologically the teenage and adult brain are different, we must now look to the more subjective part of the essay question, to why adolescents may need a brain which works in different ways. Firstly, it is clear that the primary reason for adolescence is to develop independence from a caregiver, and from this, it can be said that the age-old instinct teenagers feel to find a peer group is incredibly useful, as it provides the first steps towards them being their own person. In addition to this, this want to form a social group gives birth to a whole new set of social skills, preparing the teenager for adulthood, and for forming relationships in the future – this is perhaps most significant, as it has been proven in various studies that relationships are the core to wellbeing on many levels. The impulsiveness caused by the absence of a fully developed PFC may not be an impediment to progress, as it first seems, but instead, allows humanity to explore, and push the boundaries of life. This spawns innovation and a different outlook on the world, and as adolescents take risks, they build up a sense of right and wrong. Finally, and perhaps most appropriately in the setting this is being written, the increased response to rewards in our teenage years means that the brain is outfitted for education, and strives towards the ultimate reward – knowledge.

Despite all this, it seems wrong to me that all the positive aspects of the teenage brain be listed, without looking at the negatives, the ways in which it is a hindrance rather than a help. It may provide teenagers with new social skills and so on, but it cannot be said that in some ways, an adult-like brain may be more useful to teenagers. Looking deeper into this evolutionary need for acceptance into a group, it can be seen how this has its downside – peer pressure. Teens can be so intent on breaking into a group that they will do anything asked of them, ignoring their moral compass and following their friends instead (Siegel, 2016). With this, a teenager's drive to try new things can sometimes lead to experimentation with dangerous substances, and they are more likely to form addictions to such substances than at any other time in their lives, due to their brain's increased response to rewards – in this case, getting high. Sleep deprivation is not only destructive to a teenager's mood, but also to their development, as it is during sleep that the pituitary gland produces an essential growth hormone. Finally, it is during adolescence that teenagers are most susceptible to mental illness, due to the way their brain develops and matures. Overall, the teenage brain may be a blessing in some ways, but in many others, it is a curse.

Within this essay, a great deal of information and opinions have been included, from biology to personal views, and from all this, it is clear that a conclusion can be drawn. It is obvious to us now that the teenage brain is very different from that of an adult, not only in terms of its anatomy, but also in the way it perceives the world. Teenagers make decisions biased by emotion, gut reaction and the promise of a reward. They take risks simply because it makes them feel alive. They step away from the endless love of their parents because at the back of their minds, they feel if they don't, survival is unlikely. These differences, it is now clear to see, are in some ways beneficial to a teenager's development, but in others, they hold a teenager back, or set them on the wrong path into adulthood. All this can be validated by studies, tests, and experiments, but even now, with the technology the human race possesses, we are still only scratching the surface of the teenage and adult brain, and it is clear that there is still so much we do not yet know - so much, in fact, that we may never truly understand the human brain, never truly understand who we are as people.

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