Are brains "gay"?

Anatomically, at least on the surface, there is nothing to distinguish homosexuals from heterosexuals. With rare exceptions, homosexual genitalia are no different from heterosexual genitalia. If there are anatomical and biochemical differences researchers have had to look a lot further for them, and this has lead them to search for differences within the brain. Is sexuality somehow hard-wired into the micro-structure of the brain?

Our conclusion in this chapter, based on recent research, is that an individual's experiences of life rather than pre-natal conditions predominate in forming brain anatomy, and the onus is now on those thinking differently to supply proof. We conclude that brains are not innately gay or-straight, but *are* shaped later by repeated fantasising and experience.

Early organisational-activation theory superseded

In 1959 University of Kansas researchers Charles Phoenix and colleagues[1] published a theory with some experimental support, that said the prenatal testosterone surge in mammals organised the brain in a male fashion. We explained in Chapter Seven that, as a boy grows in the womb, he will be subjected to a sudden strong surge of testosterone at 8-24 weeks, so that the male reproductive organs will develop. This sudden surge also results in a spurt of growth in the brain.

The Kansas theory—called the organisational-activation hypothesis—says this male brain organisational structure then lies almost dormant until puberty when it is activated, and cannot be changed or influenced between the pre-natal surge and puberty. It seemed reasonable at the time. Presumably a lesser testosterone surge than normal might explain male homosexuality. (There would have to be a small surge in females to explain lesbianism but this was unknown for females, and was a weak point of the theory.)

But it seemed quite possible that a boy's brain might be different from a girl's, and that the brain of a male homosexual might be different from either, or maybe more like the brain of the opposite sex, and that one could find this by examining adult brains.

Research efforts in the early nineties particularly, reflected the idea that brain structure was rigid and unchanging, making sexual orientation also inevitable and unchangeable, and able to be detected in brain micro-structure—and we will look at those studies too in this chapter.

What recent research shows

However, neuroscientists no longer believe that the brain is once-for-all organised in a male way during gestation, or that brain structure is rigid and unchanging. Here is what recent research does show:

- There are previously unknown sex-hormone surges much later than 24 weeks, including just before and after birth and they are more important.
- Male and female brains are not significantly structurally different at birth. So, how could a "homosexual" brain be identified?
- The environment affects male-female brain development from birth to puberty and beyond.
- We can alter the microstructure of our brains even in adulthood. The truth is that the brain is amazingly plastic, and can change its microstructure hugely in adult life in response to experiences and training, good or bad. These changes in microstructure are visible in brain scans. So are you stuck with the type of brain you were born with? Not at all. You should assume change is possible (and this should also apply to sexual orientation). The scientific consensus now is that even as an adult, *you are what you are making your brain* even though you may not be aware of the constant ongoing process.

It used to be thought that structures in the brain governed most behaviours (we could call people who thought like that, essentialists) and the onus was on objectors (whom we could call developmentalists) to show otherwise. The discoveries of the last decade or two reverse this. Behaviours (even reflexes, see Chapter Four) can change a great deal with intensive training.

In the studies which follow therefore, even if differences were reliably shown to exist between adult brains of homosexuals and heterosexuals, they would now mostly be explained by neurologists as the result of numerous repeated experiences and thinking patterns, rather than being fixed structures programming a certain sexual orientation. Because we definitely know that the brain is surprisingly plastic, essentialists must now show, not only that there are brain differences, but that these were present at birth, did not respond to training or experience, and inevitably produced their results later in life. Apart from the grave logistic difficulties in the experiments we doubt this research will ever succeed. There is now too much evidence the other way.

Innate anatomical/structural differences?

Birth to two years

Let's look first at what innate male/female differences there may be.

There is remarkably little evidence of differences between boys and girls at birth. Boys are 5 % heavier than girls and 1-2 % longer. Existing male/female differences seem statistical in nature, i.e there is huge overlap rather than two clearly defined groups. Statistical differences in the sizes of features of the brain called the corpus callosum[4] and the cerebral ventricular atrium[5] in newborns are reported (but from evidence later in this chapter these last two could be hard to replicate). These minor differences, if real, may reflect minor differences in brain function or structure but definite anatomical differences only can be seen in the mid childhood years[6] with the start of differences at ages 2-4 for at least the hypothalamus[7] (a brain organ thought to be involved in several aspects of sexual behaviour).

It has proved possible in preliminary work to show differences between the expression of genes on the Y-(male) Chromosome in male and female fetal brains. One third of the genes were expressed in males but (obviously!) not in females.[47] This work needs replication but might for the first time show that there is not just an overlap, but two distinct classes in a male/female property. Even so, the resulting differences after birth in behaviour, biochemistry and brain micro-structure, as discussed, seem very small indeed.

We emphasise that all other brain-related differences demonstrated so far at birth are statistical only and there is enormous overlap between male and female, unlike the very marked genital differences at birth.

Behavioural differences in male and female newborns?

Might behavioural differences be a more reliable measure of brain differences? Perhaps our instruments are simply not precise enough to detect infant brain structural differences? However we see the same huge overlap in behaviour between boys and girls.

Newborn girls have a greater sensitivity to electric shock, react more to a puff of cold air on the skin, make more fine gestures,[2] but many of these differences may not originate in the brain.

There is a definite difference in sleep/wakefulness maturation, which lags in boys, and seems a genuine brain difference.[3]

In the first four days girls imitate parents faster and more often.[2] Similarly NYU psychologist Martin Hoffman showed newborn girls pay more attention to the cries of other babies than newborn boys do.[8] There is a statistical increase at twelve months in the attention paid to faces by infant girls compared with boys.[9] Much later boy babies seem readier to crawl away from their mothers, and take longer to come back; by age two, boys and girls react to play-blocks in a different manner; boys make structures which are taller, girls make ones which are more spread out, and boys build better bridges. These differences are not clear-cut—there is huge overlap. And how much of the difference is from

the intense socialization they experience in the first few years? In Chapter Three, we mentioned how differently strangers treat even newborn babies once they think they know what sex they are. Many of the behavioural differences may simply result from different socialization. As New York brain researcher Byne said 15 years ago (and there has been no change), "No presumed sexually dimorphic cognitive or behavioral brain function has been shown to be independent of learning and experience."[10] In view of the known plasticity of the brain the best interpretation is that any behavioural differences have resulted more from different activities and experiences, rather than innate structures.

Brain development points to strong environment input

Boston brain researcher Shatz[11] says that when a baby is born, its brain is only one quarter of the size of the adult brain, and many of the neural connections are only established in the first three years through the stimulation and exercise which babies receive. This proceeds with extraordinary intensity; after only one year the brain is already 70 % of adult size. At the point of peak formation of neural paths this corresponds to two million fresh connections *every second*.

This leads to two other brief arguments in favour of an environmentally-based sexuality.

- If only about one quarter of the neurons in the adult brain are present at birth, and the form and structure of the remaining 75 % that develop, depend heavily on learning, experience, exercise and behaviour, then there are grounds for arguing that about one quarter of brain structure is biologically fixed and three quarters is the result of environmental interaction. We could further argue that because the child experiences so little in the womb in comparison with the bombardment of stimuli he or she begins to receive after birth, the environmental contribution to brain micro-structure is in fact, even at a conservative estimate, much closer to 90 %. (This roughly approximates the 90 % environmental and 10 % biological contributions to sexuality proposed in many of the chapters of this book.)

- The DNA in all 23 pairs of chromosomes in a single fertilized cell is three billion rungs long (See Chapter One), but there are 200,000 billion synapses or neuron junctions in the brain. Even if each rung coded for one junction (which it doesn't, see Chapter One) all the rungs together could only specify about one junction in 66,000![12] The rest would have to develop in processes some distance removed from genetic specifications—in other words, under the influence of the wider environment. DNA can specify a negligibly small fraction of neuronal details.

There is also nothing permanent either about changes to brain microstructure as a result of learning and activity. Measurements of (radioactive) carbon-14 in human brains show that the average carbon atom stays about seven years in brain tissues. This means that the complete material of the brain is changed during a lifetime by substitutions of different atoms and brain cells—even in "permanent" nerve tissue.[13] Nothing is hard-wired beyond possibility of change. If no efforts are being made to change anything the replacement atoms will go in the same places and there will be no structural change. But if an effort is being made, some change in structure is possible. Anyone determined to change any behaviour should be able to make a substantial difference in thinking and habit patterns within a decade, but usually much sooner.

Biochemical male/female differences in rats depend on environment

We now look at recent research showing that male/female brain differentiation in rats is strongly influenced by the environment—particularly by maternal grooming. This probably has implications for human brain development.

This work on rats in the University of Virginia School of Medicine[14] is important. Researchers couldn't find any male/female biochemical differences in rat brains during all of pregnancy, in the places where they expected them—the amygdala, pre-optic area and hypothalamus. Instead there was a huge male/female difference (30 %) in the cortex and hippocampus a few days before birth, as measured by both acetyl and methyl additions to the histone proteins (refer to Chapter One for the roles of these biochemicals). The differences in the cortex and hippocampus seem to lead to male or female processing and memory differences—let's call them different thinking styles. But the acetyl groups dropped back to the same levels in both males and females in the first six days after birth, i.e the difference dropped from 30 % to zero. This doesn't seem to reflect a permanent differentiation between male and female brain structures. The 30 % male/female difference in the methyl groups occurred a few days after the acetyl, but remained different in males and females after birth. (Is all this somehow connected with the testosterone surge for rats in the few days before birth and the surge in the first few days after birth? Does the same type of thing happen to humans?)

So, there are real biochemical differences in rat brains between male and female, but these are mainly the type of difference which is strongly affected by the environment—especially maternal grooming which we look at now.

Maternal interaction and grooming

Maternal interaction with the newborn rats was found to have a profound effect on the structure of the brain and later full heterosexual orientation. Even rats need their mothers! If rats are deliberately brought up with mothers absent, in an echo of the appalling effects of complete maternal deprivation on children described in Chapter Three, neither rat sex develops full heterosexual orientation but behaves in rather stunted male and female ways,[14] and their brains are observably anatomically and biochemically different from maternally groomed rats. The absence of the mother has led to brain changes.

With this clue from the rats it is probably not surprising that institutionalized children (who have had no mothering) have difficulties in later opposite-sex relationships. The early prenatal, the late prenatal, the early postnatal and pubertal testosterone/estrogen surges were not enough on their own to fully sexually program the rats. They also needed maternal presence and grooming. Similarly the hormonal surges were not enough on their own to fully gender-program the brains of institutionalised children who had no mothering. (This is not to say that very early damage is permanent; later nurture can reverse early damage.)

It is now known that the original early testosterone surge in human males is only the first of four—as it is in rats. There is a second one in the last nine weeks of pregnancy, a third in the first six months after birth, and of course the one at puberty.[15,16] The latter three last much longer than the first one, and may well be predominant influences. (There seem to be some different immediately post-birth surges for girls, and they may include female hormones).

The neuroscientists observe that the largest anatomical changes making brains sexually dimorphic (though it takes an expert to tell) are during puberty[17] and the longer the hormonal exposure the greater the differentiation. They believe puberty is one of the factors in development of male and female and not merely an activation of a previously existing state as the organisational activation hypothesis held. As summarized by Kauffman,[18] "most identified sex differences in the brain and behavior are produced under the influence of perinatal sex steroid signalling." In other words, produced by post-birth influences, and these can be environmentally influenced.

As a generality, MRI (Magnetic Resonance Imaging) scans of twins in early adulthood show that environmental influences are greatest on those brain regions which are the slowest maturing[19] —and regions associated with male-female differences are among these.

The idea of sexual identity established before birth for all time is therefore unlikely. The evidence is that post-natal training and experience are mostly responsible for the microstructure of brains.

Nineties studies claiming homosexual-heterosexual brain differences

We now look at earlier research looking for innate differences between homosexual and heterosexual brains. This research has reasonable aims, but we will see that in fact almost no differences

have been established, and for those very few that have, they may well be the result of past experiences or thinking patterns.

Comparisons of heterosexual and homosexual brains

LeVay and the hypothalamus

In the seventies and eighties, thinking that brain differences dictated function, researchers began to look for microscopic sex differences in the adult brains of homosexuals and heterosexuals, men and women. Now, reports of structural sex differences abound, but the most consistently replicable finding is that the brain is larger in men than in women.[1] Some research has focused on clusters of cells in the part of the brain called the hypothalamus, targeted because of its associations with sexual functions. Specifically research focused on a cluster of cells in the hypothalamus called the INAH-3. Three out of four studies found it to be larger in men than in women.[10] But it was a study of the hypothalamus in 1991, that generated most interest and controversy. A gay scientist, LeVay, formerly of the Salk Institute, claimed that the INAH-3 was smaller in homosexual men than in heterosexual men;[20] in other words, it was more like a woman's.

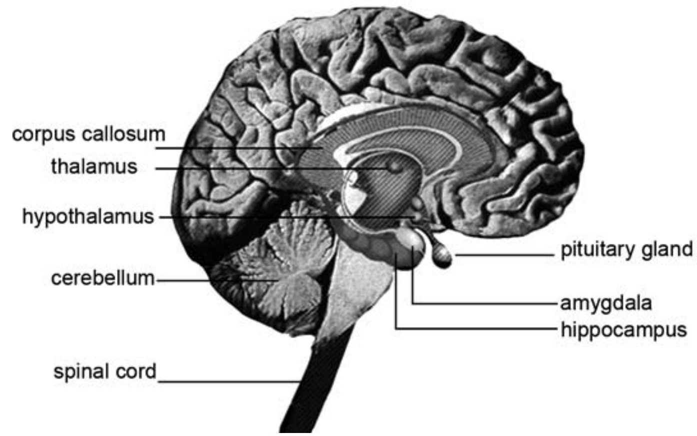

Figure 21. Brain structure viewed from right side

Although he originally commented about his findings: "It's one more nail in the coffin of critics who argue that homosexuality is a choice and thus immoral,"[20] when he is pressed, LeVay is more moderate. He says "the results do not allow one to decide if the size of the INAH-3 in an individual is the cause or consequence of that individual's sexual orientation."[20] In other words, intense homosexual behaviour could have created the difference.

The results have not been replicated

A much more careful repetition of LeVay's study was done by Byne.[21] It included "blind" work; in other words, the researchers who looked at the cells of the INAH-3 under the microscope had no idea whether the subject was a man or woman, gay or straight. The study did confirm that there was a real male-female difference in the size of INAH-3 cells. But it did not find LeVay's difference between gay and straight brains. LeVay's research is not replicable.

The suprachiasmatic nucleus

There has also been a report that the size of another cluster of cells in the hypothalamus, the suprachiasmatic nucleus, is larger in homosexual men than in heterosexual men.[22] But the study has never been corroborated, and probably won't be, according to two experts in the field, Byne and Parsons[23] who maintain that the size of this nucleus in humans does not vary with sex, and is therefore even less likely to vary with sexual orientation. "Few studies of this sort have proved to be replicable in the past," they say.

The brain commissures

The anterior commissure

Structures in the brain called commissures, attracted attention in 1992, with public announcements that the anterior commissure, a "cable" of nerve fibres connecting the two sides of the brain, is larger in women and homosexual men than in heterosexual men[24] (The anterior commissure is out of sight in **Figure 21**, but is to the right of the corpus callosum). But the study also needs verification. A study (in 1988) which looked at this structure found the opposite: the anterior commissure was significantly larger in men than women. In addition, there was a huge overlap between homosexuals and heterosexuals in the 1992 study (in 27 of a total sample of 30 homosexual men, the size of the anterior commissure fell within the range established for thirty heterosexual men).[10] The latest study[25] again found no difference, and this appears to be another proposed brain structure whose significance is in the very doubtful category.

The corpus callosum

There has also been speculation that part of the corpus callosum in male homosexuals is more like that found in the female brain than in the heterosexual male brain. (The corpus callosum is the largest cable of fibres connecting the two sides of the brain; see Figure 21). There have been twenty-three studies on the corpus callosum yielding conflicting results. Although the initial study found that the splenium of the corpus callosum was larger and more bulbous in women than in men, none of the other twenty-two studies was able to reproduce the sex difference in size. Even some of the negative studies were misinterpreted as successful replications.[23] Since that review there have been many more studies, and after a review of 49 studies it has now been concluded that all apparent male/female differences are nullified by brain size variations.[26] Such conflicting results for gender differences make nonsense of any attempts to claim male homosexual brains are more like female brains. However one study now argues a small part of the corpus callosum rather than the whole, differs in homosexual and heterosexual people.[27] This appears to be the cycle of assertion and (probable) lack of confirmation, starting all over again.

Summary

The best summary of these older studies is: reliable differences have not been shown.

Modern studies also claiming heterosexual/homosexual brain differences

More recent studies may be somewhat more reliable, because they are now often done "blind" eliminating possible bias. These studies have observed the hypothalamuses of male and female homosexuals have a different response from those of heterosexuals to some biochemicals called pheromones—the substances related to the sex hormones which correspond to each sex and can be detected by the nose.[28,29] The responses of homosexual people are partly like those of the opposite sex rather than the same sex. Similarly they find a difference for transgender people, with a shift towards the response of the opposite sex even without sexual experience.[30] (However we see later that imagination alone is sufficient to change the microstructure and responses of the brain.) Similarly the studies find different cerebral asymmetry in the homosexual subjects and assert, "The results cannot be primarily ascribed to learned effects".[31] They say this because parts of the brain like the amygdala are involved, which the researchers argue are not obviously involved in sexuality, being more related to fear. However other studies of brain activation patterns upon sexual arousal (it was inevitable researchers would do this!) are very variable, and sometimes do include changes in the activity of the amygdala.

Summary

In general for these studies, there is still substantial overlap between the results for homosexual and heterosexual.

These recent studies are about as statistically significant as the older studies, but we (somewhat optimistically) hope they may prove a little more reproducible. However they have not excluded learning effects.

The research effort looking for male/female (and therefore sexual orientation) brain differences may easily be on the wrong track. Byne[32] says that the amount of testosterone needed for masculine identity is so low, and the outcomes in even genetically identical people so variable, that it is "very unlikely there is a specifically male organisation in the brain."

We predict that some research may eventually show real and replicable biochemical and micro-structural differences between

homosexual and heterosexual brains, but as the next section in this chapter shows, this is primarily the result of long-term and frequent behaviour—training, if you like.

Brain plasticity

It is fair to say the brain, but particularly the immature brain, is like a computer which is constantly reprogramming itself, but including genuinely random actions as well. Particularly in children, neurons fire at random, and if that neural path is reinforced through experiences the path becomes fairly permanent, though not set in concrete. If it is not reinforced, the path becomes hard to excite, and eventually its neurons get pruned. Extensive stimulation is needed or pathways do not develop, and some periods are more important for certain kinds of stimulation than others. For example, if a child is deprived of light to the eyes in a critical early period, it develops childhood cataracts and becomes blind. If an adult is deprived of light for a few weeks, no such damage happens.[33]

Similarly if a child does not hear the different "l" and "r" sounds in adult's speech (for example in Japan) they will find it hard as an adult to hear any difference, let alone learn to pronounce it, but even so, enough concentrated practice will slowly succeed.

The size of the brain does not change after age five but lots of internal structural change occurs.[34]

The maturation of the brain happens in many cycles of growth of neurons and pruning. The last of these cycles is in the early twenties, and cycles can vary from a few months to several years.[35] For each growth cycle, experiences reinforce some of the neuronal pathways and the rest get pruned. One consequence of this is the important lesson, *Don't take too much notice of assertions about sexual orientation in adolescence.* Change is still happening. For any adolescent reading this—don't prematurely label yourself as SSA, you will probably change! The changes in adolescence are described in detail in Chapter Twelve.

Changes also take place in the adult brain, particularly with training. Monkey experiments have shown that artificial exercise of three digits on the hand increases the area of the brain associated with those fingers and decreases the other regions proportionately.[33] Violinists have a grossly enlarged area of the brain devoted to the fingers of their left hands. Non-jugglers who learn a juggling routine for three months produce observable small changes in the small-scale structure of the brain, and these changes can also be reversed if juggling stops.[36] Also important is that mental rehearsal of some physical skills can be almost as effective as the real thing. Thinking about something changes your brain. One of several examples is internet addiction. It does not involve new physical skills but mainly brain activity, however it causes detectable changes in the grey matter of the brain.[37] Now consider: how many times do most people think about sexual activities? How much brain change would you expect? Similarly Breedlove[38] showed that sexual experience altered neuronal size in rats by 15-20 % . Sex, probably even thinking about sex, alters the brain.

London taxi drivers have an enlarged area of the brain dealing with navigation. Is this innate? No. London bus drivers on set routes did not have this enlarged area, and after retirement of the taxi drivers, the brain area involved diminished.[39] Taxi-drivers were not born that way, but developed the brain area through huge amounts of navigation and learning, and only maintained it through constant use.

We change our brains at the micro-level through the way we exercise, and anything we do repetitively especially if associated with pleasure, e.g sexual activity. So, if LeVay did find real differences in the brains of his subjects, this was probably the result of their homosexual activity, not the cause of it.

There is now a lot of clear evidence that environmental treatment alters the brain. Early stress in rats causes many visible changes in their brains.[40] Huge stress creating Post Traumatic Stress Disorder in humans, causes changes in the brain part called the frontal-limbic system.[41] Another researcher finds that stress and maltreatment in childhood causes changes in the corpus callosum, left neocortex, hippocampus, and amygdala.[42] Institutionalisation causes changes in the amygdala of children, related to the time spent in the institution.[43] Most of these changes are atrophy of the affected parts.

Perhaps most relevant to the present subject is the discovery that sexual abuse of girls causes age-specific brain changes. If it is at ages 9-10 the change is to the corpus callosum, if at 14-16 the frontal cortex is affected.[44]

Sexual experience affects the brain—no surprise!

We strongly recommend the book by Doidge: *The Brain that Changes Itself.*[45] This remarkable but very accessible work describes the overthrow of 20th century beliefs about the unchanging nature of the brain. The brain can change a huge amount, very encouraging news to anyone who is stuck in a habit or pattern of behaviour.

He tells many remarkable stories illustrating the brain's plasticity. One is about people who get intense pain in phantom limbs which "remain" after amputation. There is no longer any physical reason for the pain, except within the brain itself. About half the patients were able to get relief from, e.g cramp in a phantom limb, merely by intensely imagining over a long time that the imaginary limb was in a different position. In other words imagination changed the brain's perception of pain. He describes how intense exercises targeting weakly performing areas of the brain can make differences which seem almost miraculous, and how any vigorous training causes changes in the observed microstructure of the brain. The degree of training needed to be sufficient to cause great tiredness.

Doidge gives a neurological principle: *Neurons which Fire together Wire together.* In human sexuality this means that if something non-sexual is often associated with sexual arousal it will tend to become part of it. In brain maps genital response regions lie alongside the response region for feet, and Doidge wonders if this might relate to sexual fetishes involving feet. (And could it explain the Victorian ankle fetish?) It also becomes very reasonable to suppose that, e.g intense emotional focus on someone of the same sex might get triggered together with sexual excitement, and if frequently repeated ultimately seem to be very deeply ingrained homosexuality.

Because of brain plasticity it's quite possible that homosexuals could become more heterosexual and heterosexuals could become homosexual, though intense persistent work could be needed, about equivalent to thoroughly mastering a new musical instrument.

Doidge shows that various skills and behaviours are indeed organised in distinct brain regions but that the micro-details (or "brain-map") are dynamic and changing on a day-to-day basis. If one part of the brain is suddenly not used, the areas around it quickly start to recruit these unused brain cells for other purposes, reprogram them and use them, e.g parts of the brain involved in the functioning of a lost limb can be re-purposed; parts of the brain used in a now-discarded skill can be recruited for another very different skill. Doidge sums up the extraordinary plasticity of the brain with the words, *Use it or Lose it*. (We could also say, the more we use it (think and behave a certain way) the less likely we'll lose it because we're reinforcing neuronal pathways in the brain each time.)

Sometimes the loss is permanent—a childhood language can get completely lost. Sometimes it is partial—a musician may find it hard to retrieve accurately a difficult musical piece after some years. But it will return quickly if practised again.

Even if part of the brain is strongly associated with a particular sexuality it should be possible to change it. Stopping a sexual activity and avoiding stimulation of that area, while giving oneself to another absorbing brain activity for months, e.g thoroughly mastering a musical instrument, would lead to a diminishing of the intensity of that sexual response. Months is about the timescale of first significant change. That can be true for learning a musical instrument too!

A prediction of plasticity principles though not mentioned by Doidge, would be that any brain structures associated with sexual activity would be much changed in those very old people for whom such activity has long ceased. Using MRI, declines are already seen in brain activation in response to erotic stimuli in middle age compared to younger ages.[46]

Doidge's conclusion about sexuality is that "Human libido is not a hard-wired invariable biological urge, but can be curiously fickle, easily altered by our psychology and the history of our sexual

encounters", and "It's a use-it-or-lose-it brain, even where sexual desire and love are concerned." This would apply both to same-sex attraction and opposite-sex attraction.

If we train hard enough, an activity can become automatic and we pay it less conscious attention. Details of driving, throwing a ball, reading, even tying shoelaces don't and often can't demand full attention. Martial arts experts strive to reach this level of automatic response, because there is no time in a fight to work out the best counter attack. It is also particularly true of playing a musical instrument. Many of the basic techniques like chords, scales and arpeggios, are so deeply learned that we don't think about the details and indeed can't if the music is fast. Doidge says this degree of training alters brains so much that after death the brain of a musician is uniquely different to other brains.

Studies show that we make decisions, e.g to move an arm a fraction of a second before it is conscious. We have delegated even some of our decision-making to unconscious levels. This does not mean free-will is an illusion, but that we have trained ourselves to the point that the response is ingrained and automatic; part of us is now a well- functioning machine. In the same way it can seem that sexual orientation is so deeply embedded that it is innate. But, really, it is no more innate than any complex skill we have spent a long time developing. However the degree of change we're talking about does take several years of intense effort.

Summary

- Scientists have not been able to find clear structural differences between the brains of boys and girls at birth. At that stage of life their properties and functions overlap almost entirely. The same is true for behaviours rather than structures. Male and female behaviour—let alone homosexuality and heterosexuality —is not hard-wired into the brain at birth.
- Maternal interactions influence the brain structure and future sexual orientation. This means early hormonal effects on the brain are far from inevitable. In fact, only one quarter of

the brain is formed in a new-born child; the rest is developed through learning and experience (environmental input).

We can be confident that whatever male/female differences exist in adult brains (and, more are constantly being found), they will have been largely shaped by learning and behaviour.

But what learning and experiences do to the brain is not set in concrete either. Brain cells are replaced in roughly seven year cycles, meaning that new neuron pathways can be formed and old ones reshaped. Intensive exercise, training or imagination changes the brain microstructure.

We are not victims of our biology or the experiences which shape the detail of our brain. Anatomy is not destiny; change is always possible. The brain is plastic and is in a constant state of change. Indeed the question is rather: what change is *not* possible?

We would not want to say that the structure of the brain you were born with has no effect. It has. It can be profound. But that structure can also be profoundly changed, and we don't yet know the limits. They are probably sky-high.

References

1. Phoenix CH, Goy RW, Gerall AA, Young WC. 1959. Organizing action of prenatally administered testosterone propionate on the tissues mediating mating behavior in the female guinea pig. *Endocrinology* 65:369-82
2. Nagy E, Kompagne H, Orvos H, Pal A. 2007. Gender-related differences in neonatal imitation. *Infant and Child Development* 16(3):267-76
3. Cornwell AC. 1993. Sex differences in the maturation of sleep/wake patterns in high risk for SIDS infants. *Neuropediatrics* 24:8-14
4. Hwang SJ, Ji EK, Lee EK, Kim YM, Shi DY, Cheon YH, Rhyu IJ. 2004. Gender differences in the corpus collosum of neonates. *Neuroreports* 15:1029-32
5. Patel MD, Goldstein RB, Tung S, Filly RA. 1995. Fetal cerebral ventricular atrium: difference in size according to sex. *Radiology* 194:713-5
6. Chung WCJ, De Vries GJ, Swaab DF. 2002. Sexual differentiation of the bed nucleus of the stria terminalis in humans may extend into adulthood. *The Journal of Neuroscience* 22:1027-33
7. Swaab DF, Hofman MA. 1988. Sexual differentiation of the human hypothalamus: ontogeny of the sexually dimorphic nucleus of the pre-optic area. *Brain Research* 44:314-8
8. Blum D. 1997. *Sex on the brain*. New York: Penguin
9. Connellan J, Baron-Cohen S, Wheelwright S, Batki A, Ahluwalia J. 2000. Sex differences in human neonatal social perception. *Infant Behavior and Development* 23:113-8
10. Byne W. 1995. Science and belief: Psychobiological research on sexual orientation. *Journal of Homosexuality* 30:303-44
11. Shatz CJ. 1992. The developing brain. *Scientific American* 267 (March)(3):35-41
12. Koch C. 1997. Computation and the single neuron. *Nature* 385:207-10
13. Stenhouse MJ, Baxter MS. 1977. Bomb 14C as a biological tracer. *Nature* 267:828-32
14. Tsai HW, Grant PA, Rissman EF. 2009. Sex differences in histone modifications in the neonatal mouse brain. *Epigenetics* 4(1):47-53
15. Garcia-Falgueras A, Swaab DF. 2010. Sexual hormones and the brain: An essential alliance for sexual identity and sexual orientation. *Endocrine Development* 17:22-35
16. Hines M. 2008. Early androgen influences on human neural and behavioural development. *Early Human Development* 84:805-7
17. Neufang S, Specht K, Hausmann M, Gunturkun O, Herpertz-Dahlmann B, Fink GR, Konrad K. 2009. Sex differences and the impact of steroid hormones on the developing human brain. *Cerebral Cortex* 19(2):464-73
18. Kauffman AS. 2009. Sexual differentiation and the Kiss1 system: hormonal and developmental considerations. *Peptides* 30(1):83-93
19. Brun C, Lepore N, Pennec X, Lee AD, Barysheva M, Madsen SK, Avedissian C, Chou YY, de Zubicaray GI, McMahon K, Wright M, Toga AW, Thompson PM. 2009. Mapping the regional influence of genetics on brain structure variability—A Tensor-Based Morphometry study. *Neuroimage* 48(1):37-49
20. LeVay S. 1991. A difference in hypothalamus structure between heterosexual and homosexual men. *Science* 253:1034-7
21. Byne W, Lasco MS, Kemether E, Shinwari A, Edgar MA, Morgello S, Jones LB, Tobet S. 2000. The interstitial nuclei of the human anterior hypothalamus: an investigation of sexual variation in volume and cell size, number and density. *Brain Research* 856:254-8
22. Swaab DF, Gooren LJG, Hofman MA. 1995. Brain research, gender and sexual orientation. *Journal of Homosexuality* 30:283-301
23. Byne W, Parsons B. 1993. Human sexual orientation. The biologic theories reappraised. *Archives of General Psychiatry* 50:228-39
24. Allen LS, Gorski RA. 1992. Sexual orientation and the size of the anterior commissure in the human brain. *Proceedings of the National Academy of Sciences* 89:7199-202
25. Lasco MS, Jordan TJ, Edgar MA, Petito CK, Byne W. 2002. A lack of dimorphism of sex or sexual orientation in the human anterior commissure. *Brain Research* 936:95-8
26. Bishop KM, Wahlsten D. 1997. Sex differences in the human corpus callosum: myth or reality? *Neuroscience and Biobehavioral Reviews* 21(5):581-601

27. Witelson SF, Kigar DL, Scamvougeras A, Kideckel DM, Buck B, Stanchev PL, Bronskill M, Black S. 2008. Corpus callosum anatomy in right-handed homosexual and heterosexual men. *Archives of Sexual Behavior* 37(6):857-63
28. Berglund H, Lindstrom P, Savic I. 2006. Brain response to putative pheromones in lesbian women. *Proceedings of the National Academy of Sciences* 103:8269-74
29. Savic I, Berglund H, Lindstrom P. 2005. Brain response to putative pheromones in homosexual men. *Proceedings of the National Academy of Sciences* 102:7356-61
30. Berglund H, Lindstrom P, Dhejne-Helmy C, Savic I. 2008. Male-to-female transsexuals show sex-atypical hypothalamus activation when smelling odorous steroids. *Cerebral Cortex* 18(8):1900-8
31. Savic I, Lindstrom P. 2008. PET and MRI show differences in cerebral asymmetry and functional connectivity between homo- and heterosexual subjects. *Proceedings of the National Academy of Sciences* 105(27):9403-8
32. Byne W. 2006. Developmental endocrine influences on gender identity: Implications for management of disorders of sex development. *Mt Sinai Journal of Medicine* 73:950-9
33. Kandel ER, Hawkins RD. 1992. The biological basis of learning and individuality. *Scientific American* 267 (March)(3):53-60
34. Durston S, Hulshoff Pol HE, Casey BJ, Giedd JN, Buitelaar JK, van Engeland H. 2001. Anatomical MRI of the developing human brain: what have we learned? *Journal of the American Academy of Child and Adolescent Psychiatry* 40:1012-20
35. Barry RJ, Clarke AR, McCarthy R, Selikowitz M, Johnstone SJ, Rushby JA. 2004. Age and gender effects in EEG coherence: I. Developmental trends in normal children. *Clinical Neurophysiology* 115(10):2252-8
36. Draganski B, Gaser C, Busch V, Schuierer G, Bogadahn U, May A. 2004. Neuroplasticity: changes in grey matter induced by training. *Nature* 427:311-2
37. Zhou Y, Lin FC, Du YS, Qin LD, Zhao ZM, Xu JR, Lei H. 2009. Gray matter abnormalities in internet addiction: A voxel-based morphometry study. *European Journal of Radiology*
38. Breedlove M. 1997. Sex on the Brain. *Nature* 389:801
39. Maguire EA, Woollett K, Spiers HJ. 2006. London taxi drivers and bus drivers: a structural MRI and neuropsychological analysis. *Hippocampus* 16(12):1091-101
40. Mandyam CD, Crawford EF, Eisch AJ, Rivier CL, Richardson HN. 2008. Stress experienced in utero reduces sexual dichotomies in neurogenesis, microenvironment, and cell death in the adult rat hippocampus. *Developmental Neurobiology* 68(5):575-89
41. Leonard CM, Towler S, Welcome S, Halderman LK, Otto R, Eckert MA, Chiarello C. 2008. Size matters: cerebral volume influences sex differences in neuroanatomy. *Cerebral Cortex* 18(12):2920-31
42. Teicher MH, Andersen SL, Polcari A, Anderson CM, Navalta CP, Kim DM. 2003. The neurobiological consequences of early stress and childhood maltreatment. *Neuroscience and Biobehavioral Reviews* 27(1-2):33-44

43. Mehta MA, Golembo NI, Nosarti C, Colvert E, Mota A, Williams SC, Rutter M, Sonuga-Barke EJ. 2009. Amygdala, hippocampal and corpus callosum size following severe early institutional deprivation: The English and Romanian Adoptees Study Pilot. *Journal of Child Psychology and Psychiatry* 50(8):943-51
44. Andersen SL, Tomada A, Vincow ES, Valente E, Polcari A, Teicher MH. 2008. Preliminary evidence for sensitive periods in the effect of childhood sexual abuse on regional brain development. *Journal of Neuropsychiatry and Clinical Neuroscience* 20(3):292-301
45. Doidge N. 2007. *The Brain that Changes Itself*. London, UK: Penguin
46 Seo Y, Jeong B, Kim JW, Choi J. 2010. The relationship between age and brain response to visual erotic stimuli in healthy heterosexual males. *International Journal of Impotence Research* In Press
47 Reinius B, Jazin E. 2009. Prenatal sex differences in the human brain. *Molecular Psychiatry* 14:988-9