EARLY BRAIN & BIOLOGICAL DEVELOPMENT A SCIENCE IN SOCIETY SYMPOSIUM

Brain Plasticity and Behavioural Development

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Alberta family wellness initiative

Where science meets real life

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Key Points

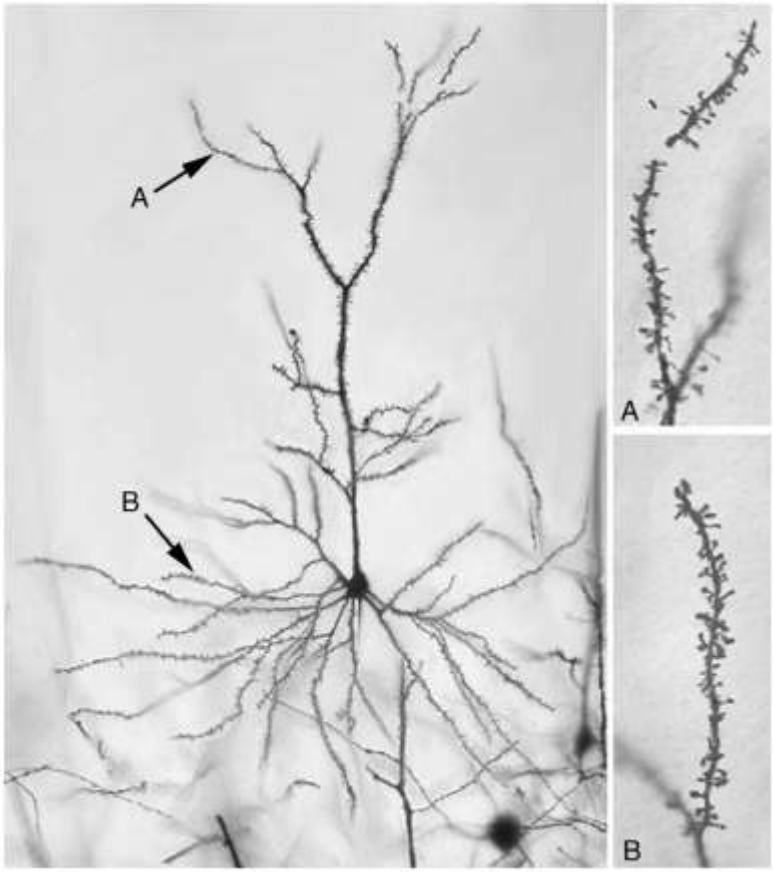
1. **Behaviours emerge as the brain develops**
2. **Brain development is prolonged**
3. **Brain structure and function is altered by experience = *brain plasticity***
4. **Experience includes a wide range of pre- and postnatal factors.**
5. **Brain and behavioural development is modulated by gene expression.**

Measuring Neural Maturation

- **Changes in neuronal organization can be shown at various levels of analysis from behaviour to molecules.**

- **I will focus on the structure of cells (neurons) and regions in the brain *because* activities of the brain can be inferred from these measures.**

Brain Cells are complex



Connection numbers can be estimated by knowing the length of the cell branches and the density of the connections.

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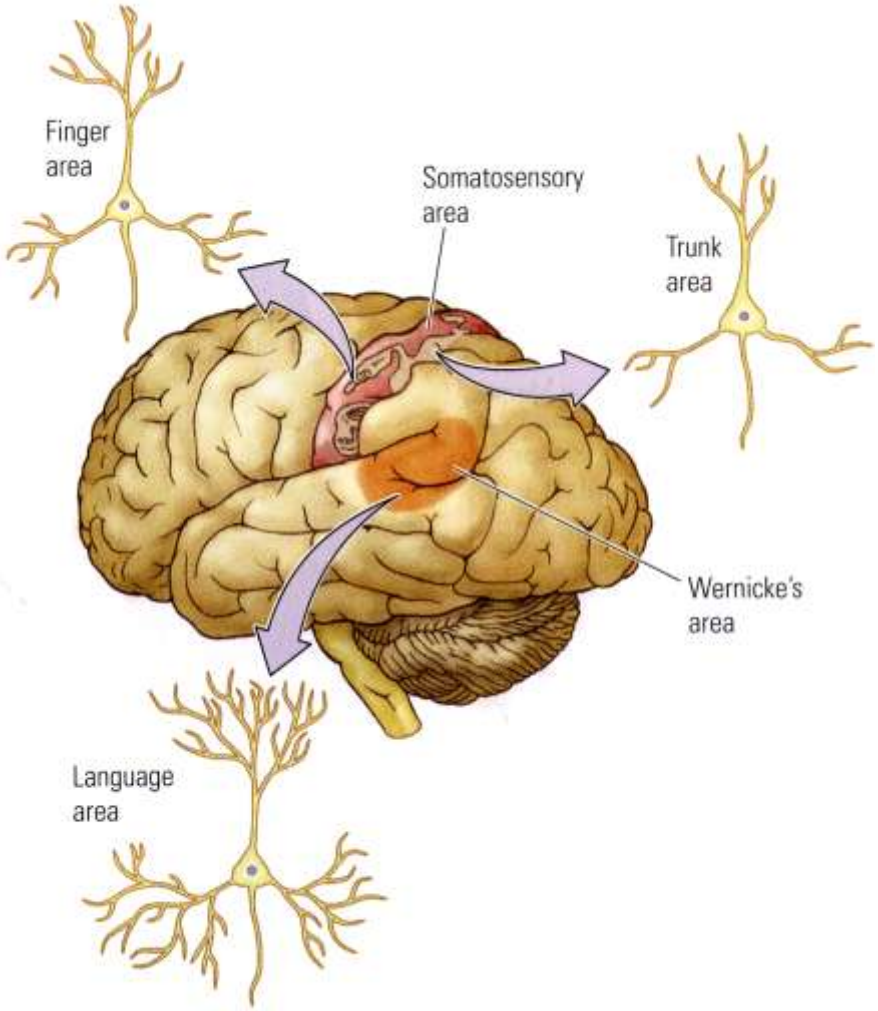
Cell Structure relates to behaviour

-Complexity
of computations
-IQ
-Occupation
-Sex



Piaget's stages of development

- The details are likely wrong but the key principle of the correlation between emerging brain and behavioural develop is important

Table 23.3 Piaget's stages of cognitive development

Typical age range	Description of the stage	Developmental phenomena
Birth to 18–24 months	*Stage 1: Sensorimotor* Experiences the world through senses and actions (looking, touching, mouthing)	Object permanence Stranger anxiety
About 2–6 years	*Stage 2: Preoperational* Represents things with words and images but lacks logical reasoning	Pretend play Egocentrism Language development
About 7–11 years	*Stage 3: Concrete operational* Thinks logically about concrete events; grasps concrete analogies and performs arithmetical operations	Conservation Mathematical transformations
About 12+ years	*Stage 4: Formal operational* Reasons abstractly	Abstract logic Potential for mature moral reasoning

Source: After D. G. Myers, *Psychology,* 5th ed. (New York: Worth Publishers, 1998), p. 89.

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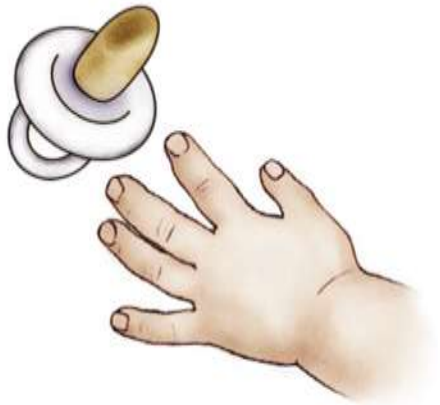
Behaviours emerge when the brain is ready for them

2 months



Orients hand toward an object and gropes to hold it.

4 months

Grasps appropriately shaped object with entire hand.

10 months

Uses pincer grasp with thumb and index finger opposed.

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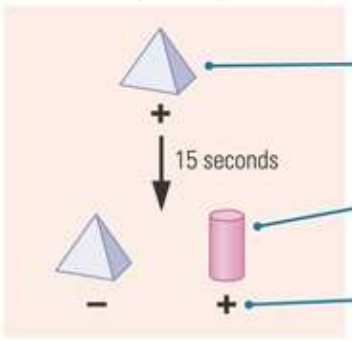
Cognitive development is not intuitive…

Procedure

I. Displacement task

II. Nonmatching-to-sample learning task

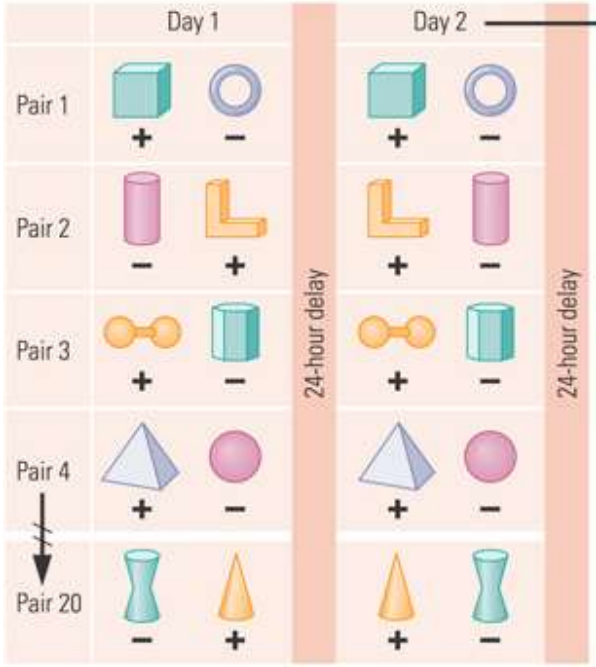


Subject is shown object that can be displaced for a food reward (+).

Preceding object and new object are presented.

Displacement of new object is rewarded with food.

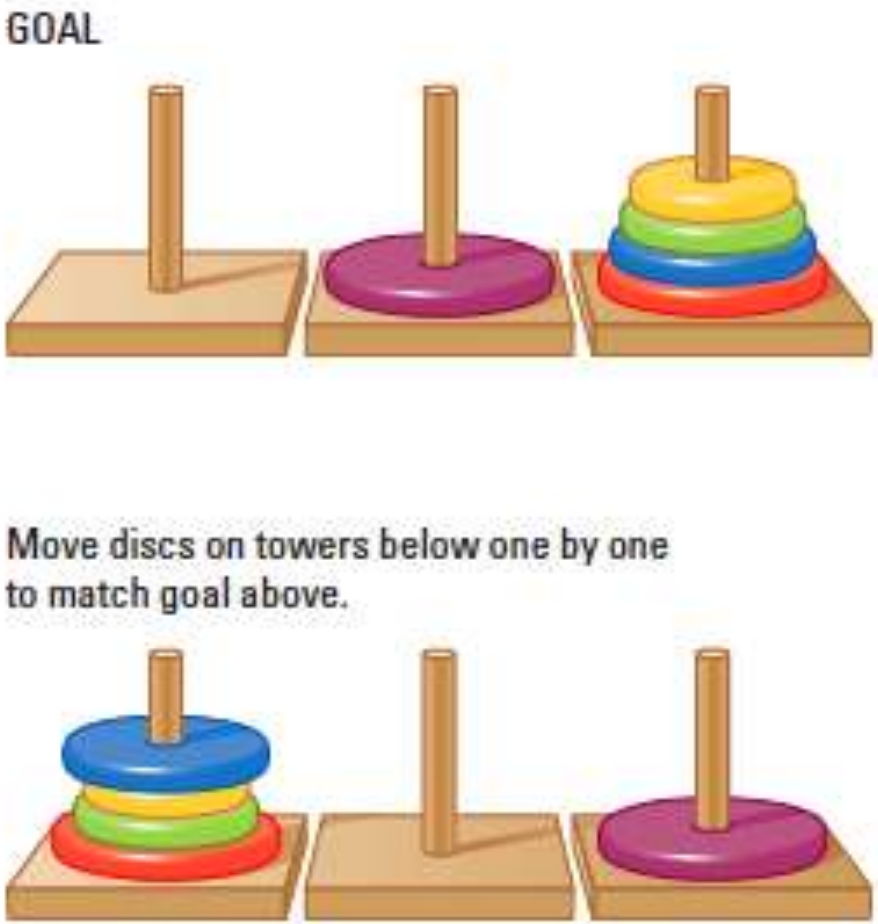
III. Concurrent-discrimination learning task



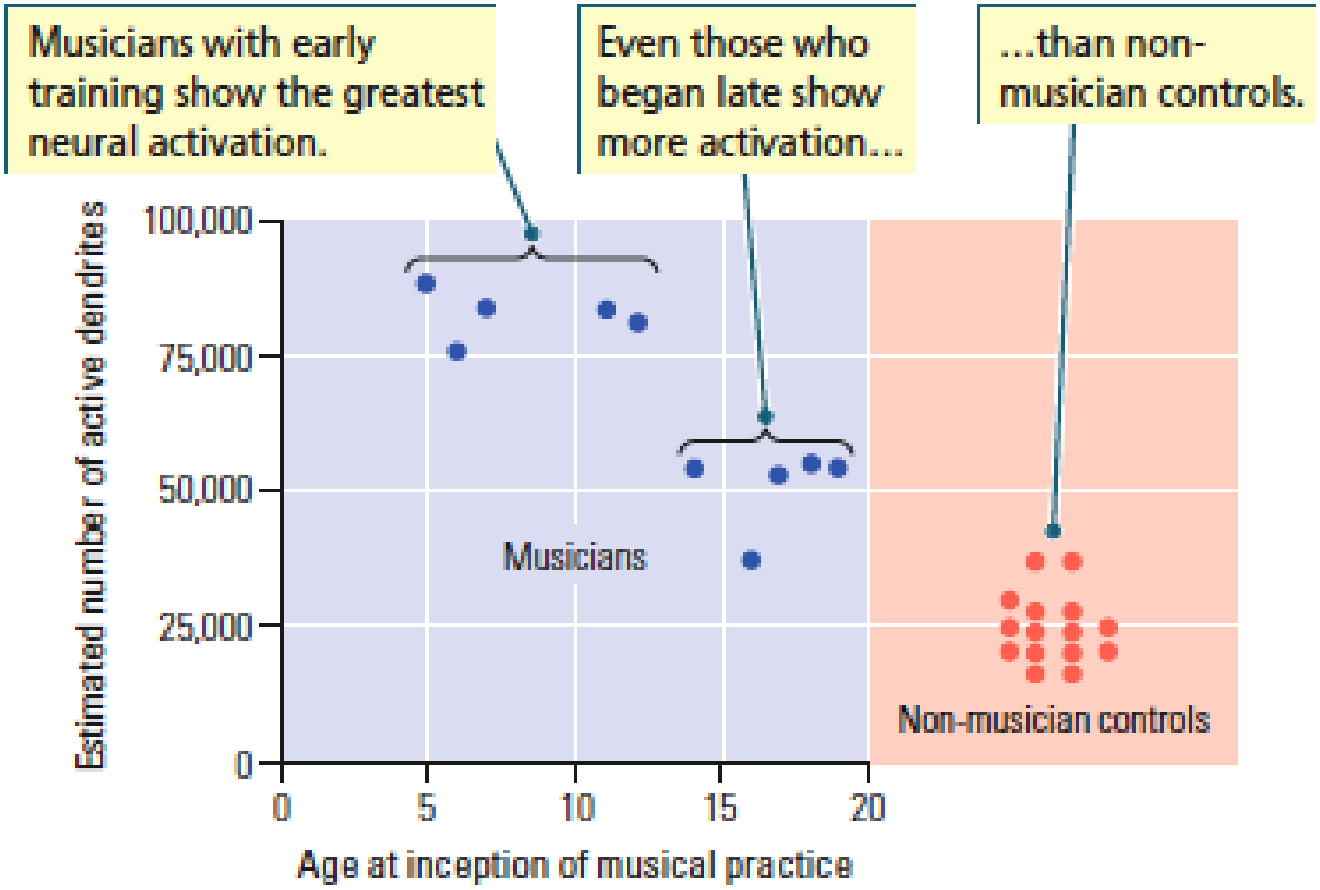
By trial and error, subjects must determine which object in each of 20 pairs should be displaced for a reward of food.

In later trials, the same subjects were presented with the 20 pairs from Day 1 in order to learn and remember which object in each pair should be displaced for the food reward.

Complex tasks may not emerge until late teens



Ability is related to synapse number



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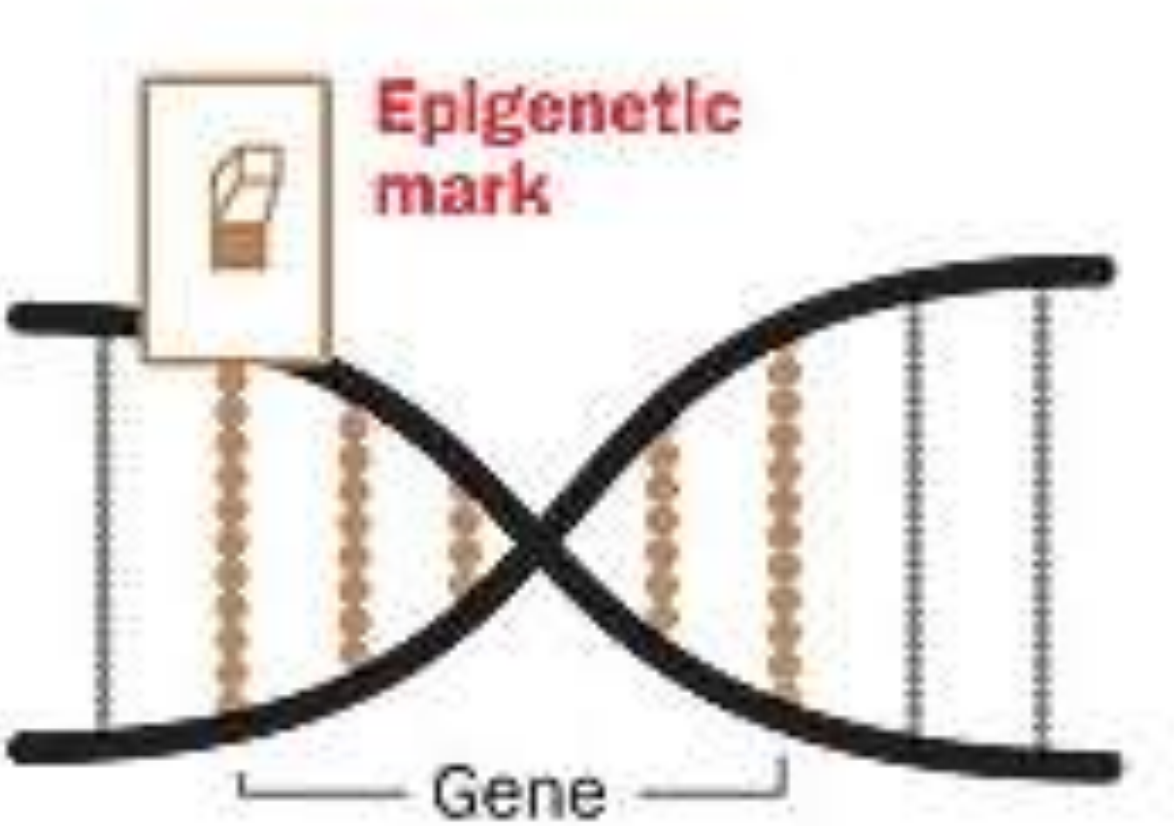
Epigenetics and brain development

All cells carry the same DNA but different cell types (brain vs bone) are very different because of gene expression differences

Genes can be switched on and off



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Brain plasticity and behaviour

Brain changes result in behavioural change.

This change is known by names such as learning, memory, addiction, maturation, ageing, recovery, fatigue, dementia, depression, PTSD, etc.

How does this happen?

Experience alters brain activity, expression of genes, brain chemistry, behaviour, and so on.

Any one of these can alter connectivity and thus function.

What is experience?

- ***Everything*** **that you encounter both pre- and postnatally as well as in adulthood…**

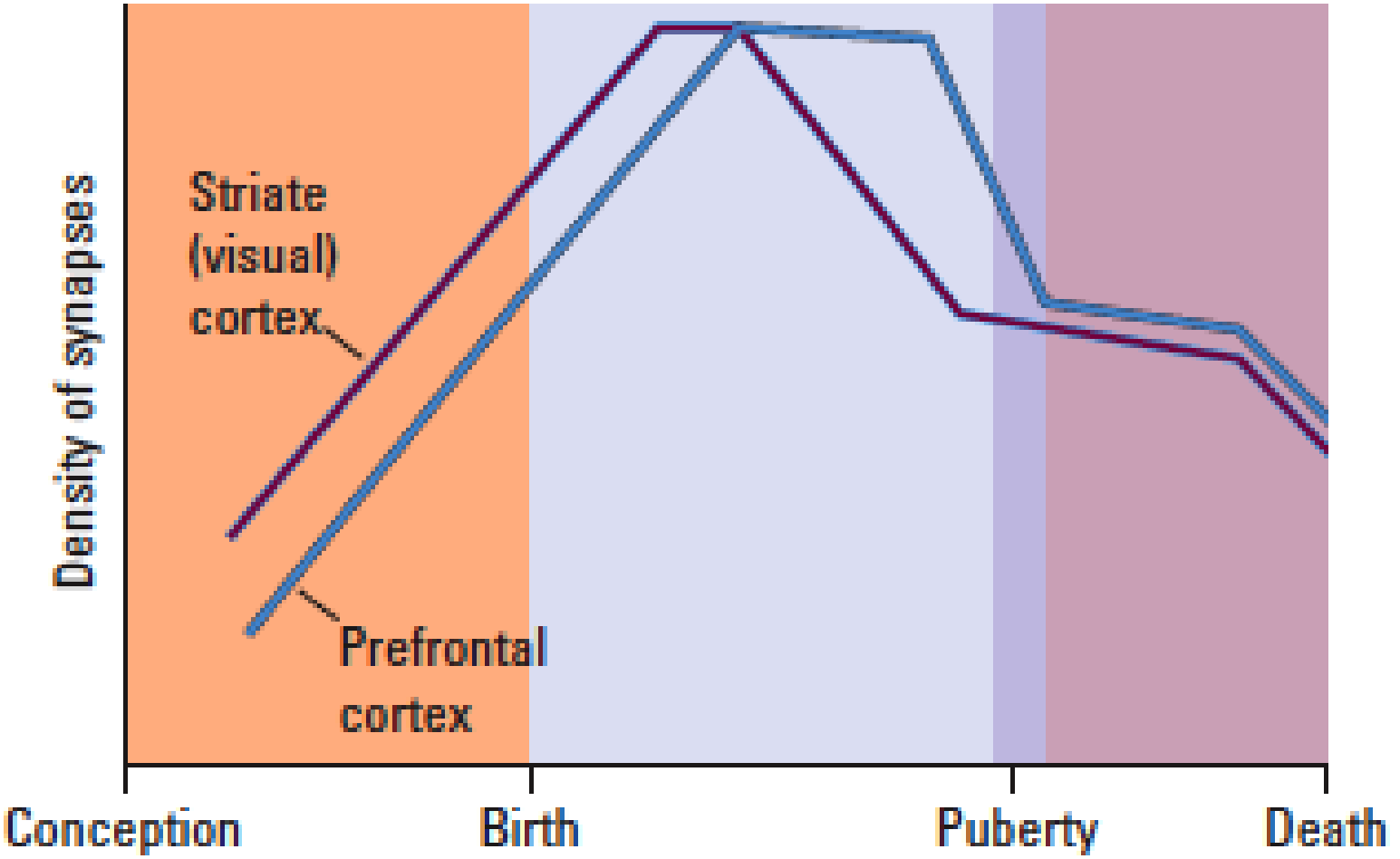
- **Examples: sounds, touch, light, food, thoughts, drugs, injury, disease…**

Development of brain

TABLE 7-1 Stages of Brain Development

1. Cell birth (neurogenesis; gliogenesis)
2. Cell migration
3. Cell differentiation
4. Cell maturation (dendrite and axon growth)
5. Synaptogenesis (formation of synapses)
6. Cell death and synaptic pruning
7. Myelogenesis (formation of myelin)

And then they are pruned out



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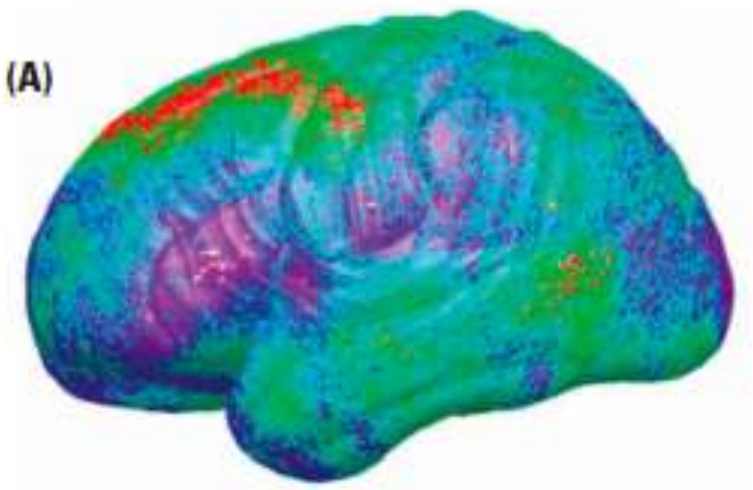
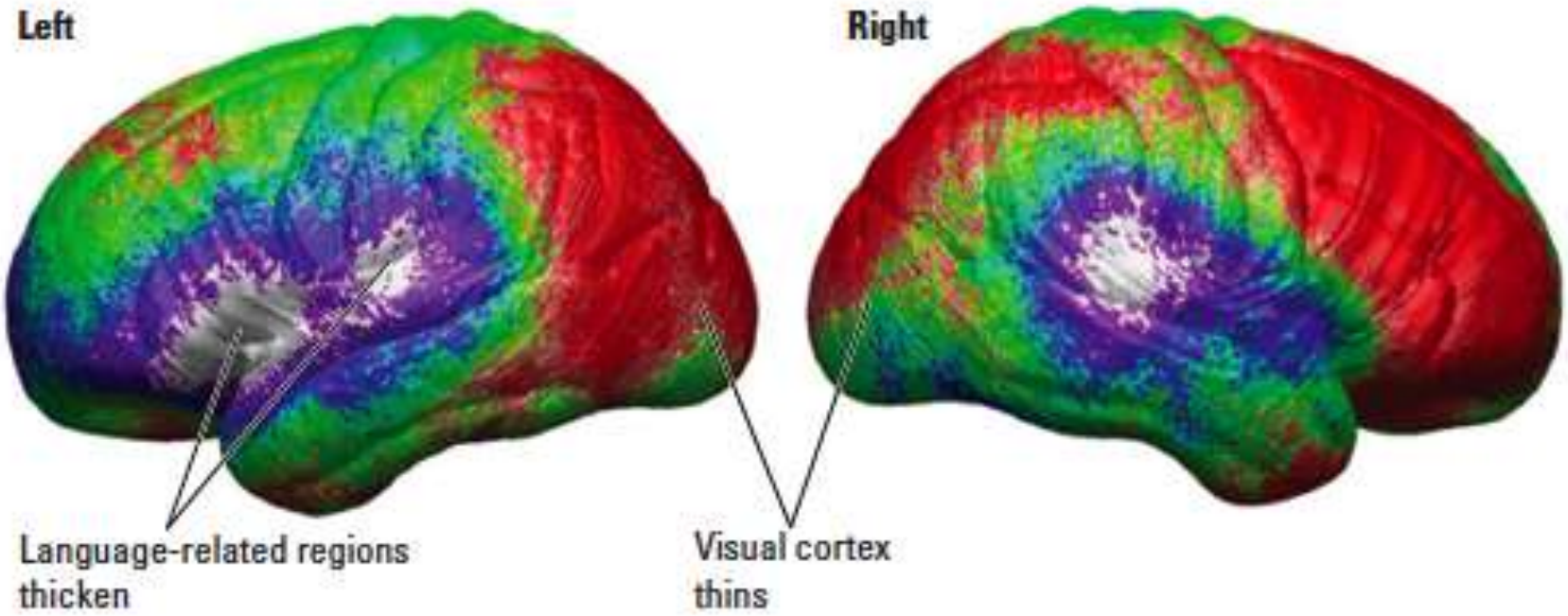
Motor Development correlates with less…

Red regions show correlation between motor development and cortical *thinning*



Vocabulary and thinning

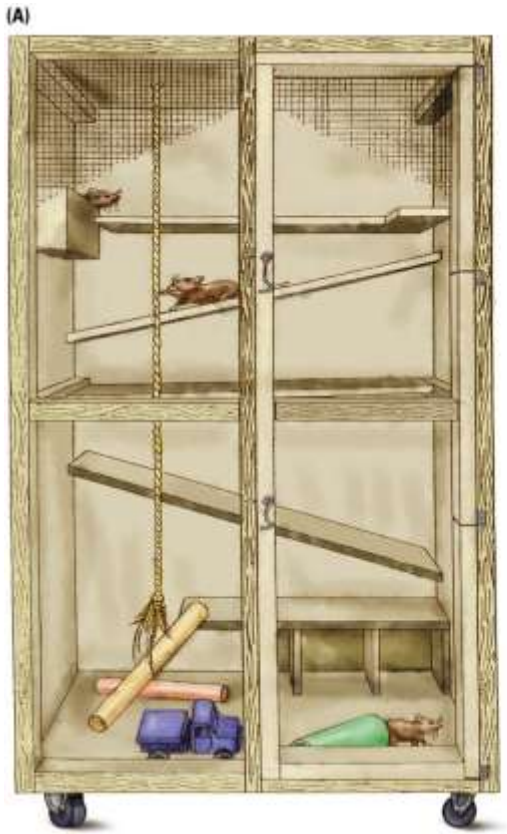
But, language is different…

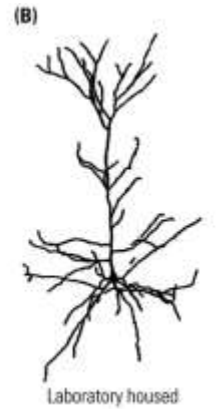


Principles are similar across all mammals

- Many factors alter brain development

1. Sensory and motor experience

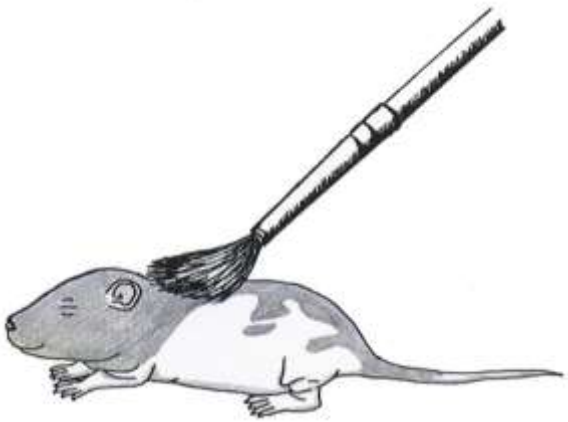




Pre- and postnatal and even pre-conception alters brain and behavioural development

Brains are bigger, have different patterns of connections & cognitive & motor behaviours are enhanced

Pre- and postnatal tactile stimulation is powerful



- And even a broad spectrum light

What happens to the brain?

- **Larger brain with more connections**
- **Enhanced cognitive & motor performance in development and adulthood**
- **Changes in the genes turned ‘on’ and ‘off’**

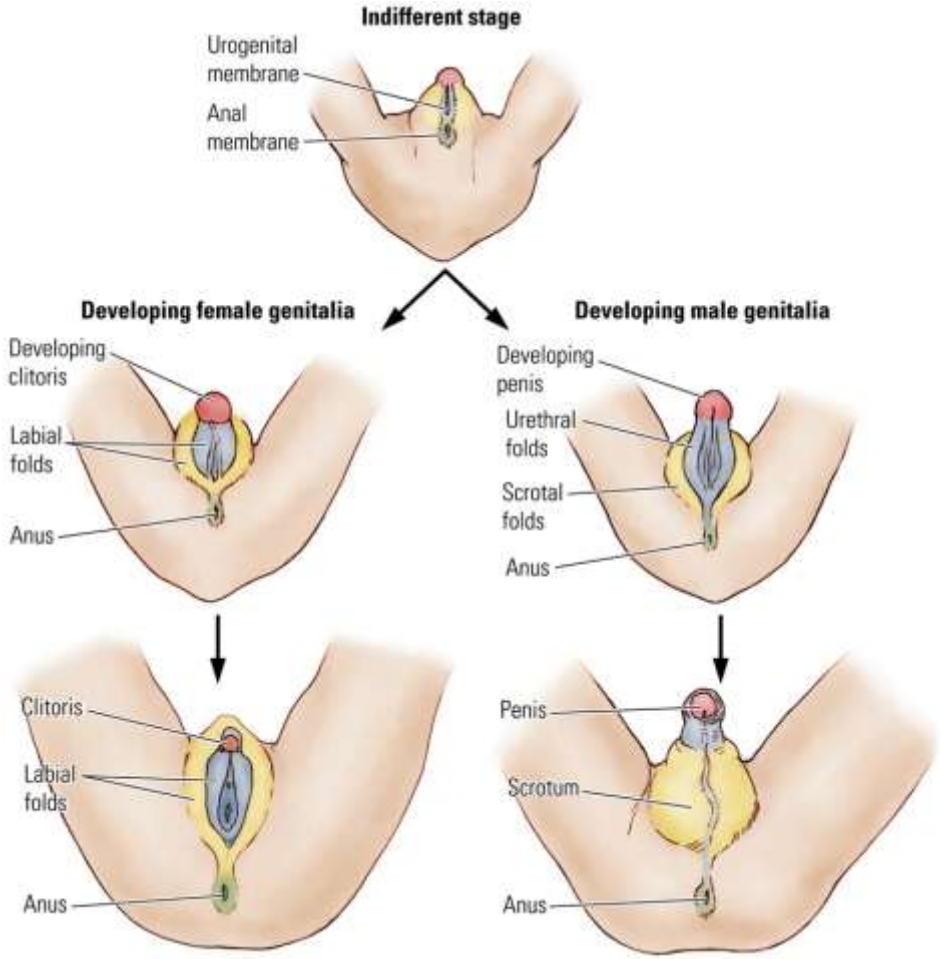
- **Experience can alter the production of proteins in the skin, which in turn can alter the brain through effects on genes.**

And the point is?

- Think about parent-infant interactions. Contact is important…

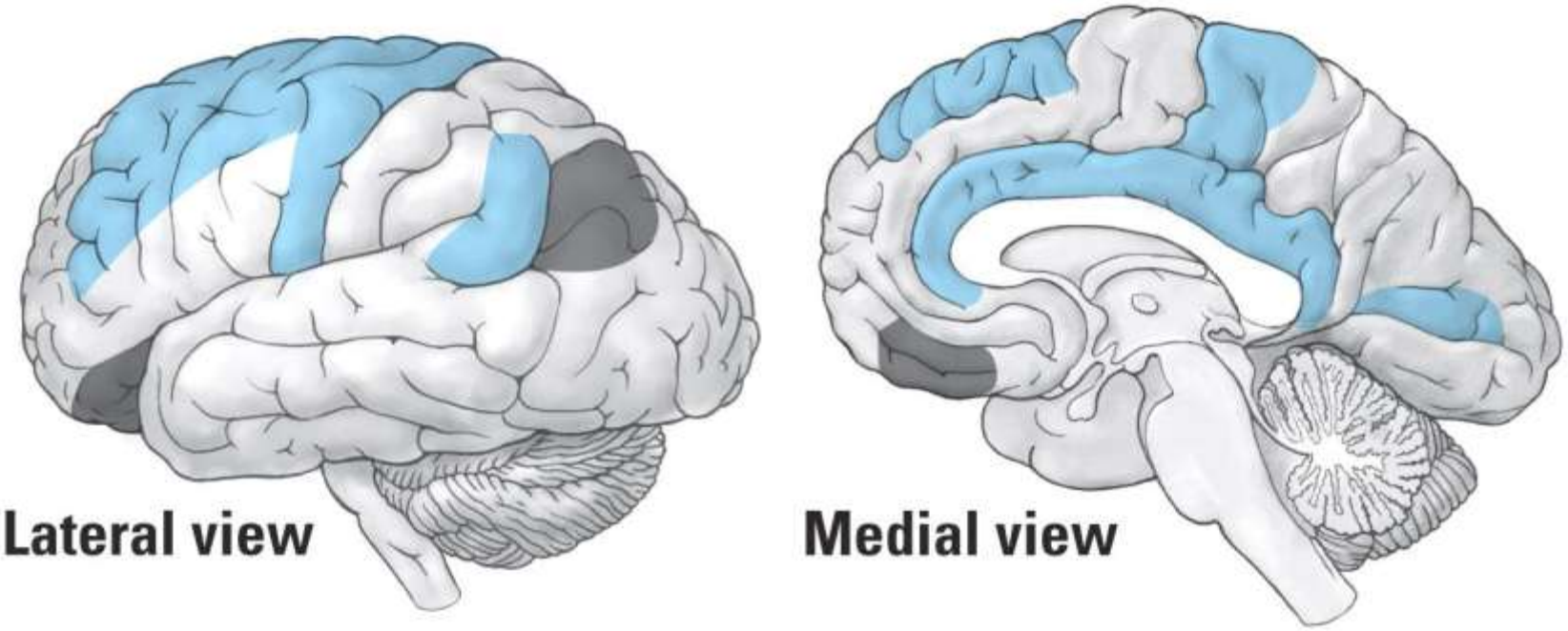
2. Hormones change more than genitals

- The brain & genitals have the same hormone receptors in development



Gonadal hormones make different brains

- Relative volume of regions in women (blue) and men (gray)



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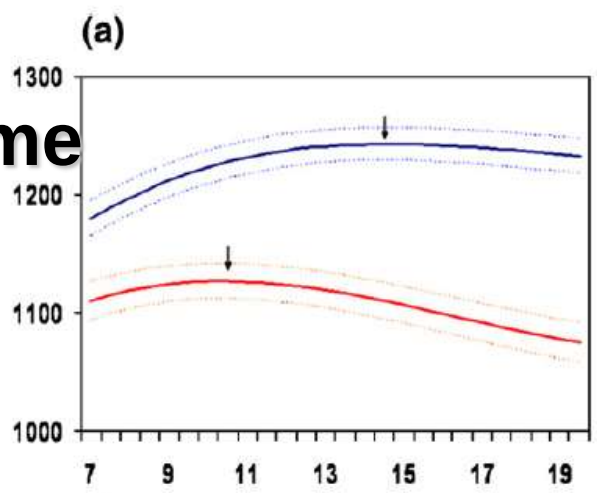
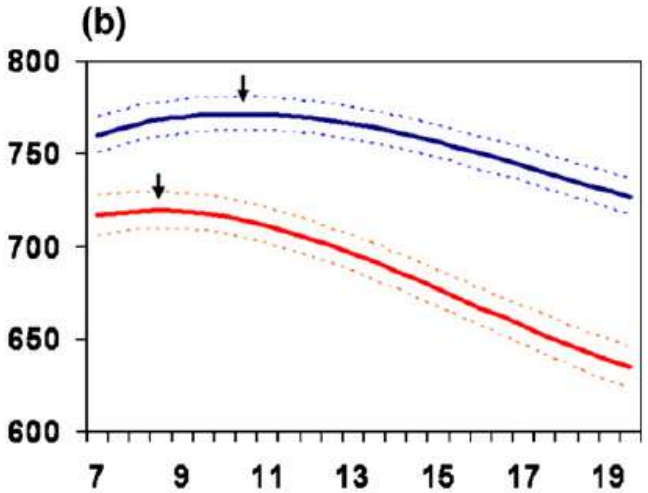
Female and Male Brains Develop Differently

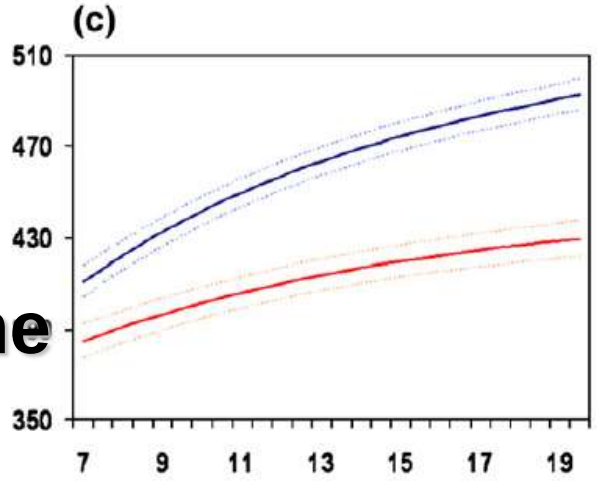
Total Volume

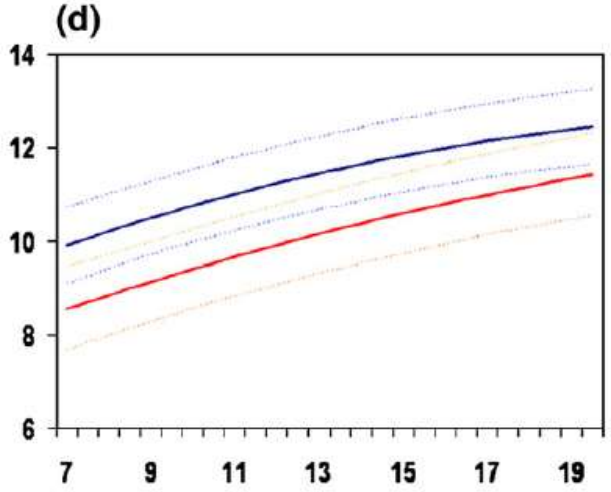




Gray Volume

White Volume





Ventricle Volume

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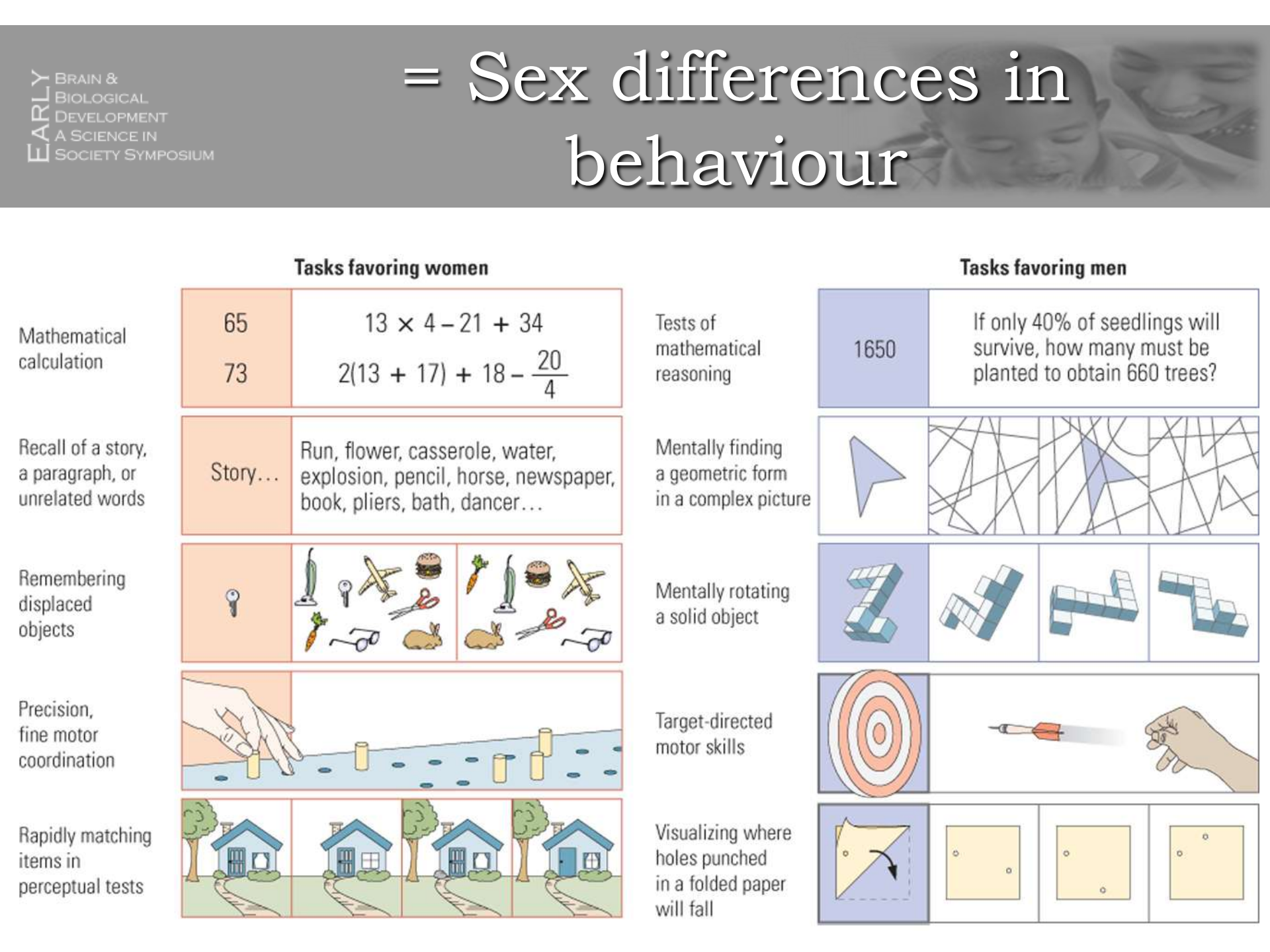
= Sex differences in behaviour

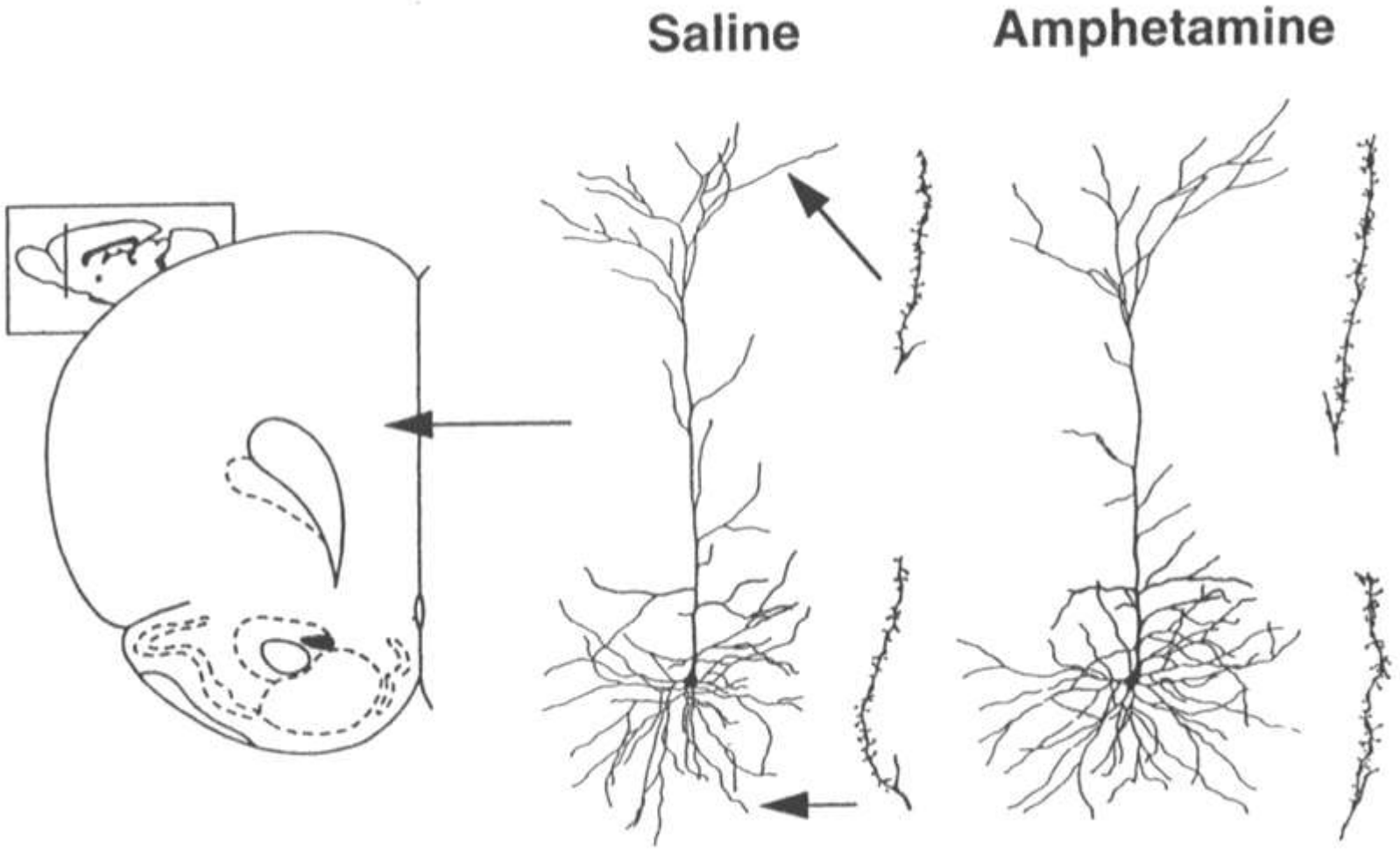


But it is more complex…

- But it is not JUST hormones. There are genes too

FIGURE 7-29 A Gynandromorph. This rare zebra finch has dull female plumage on one side of the body and bright male plumage on the other side.

3. Drugs change neuronal networks



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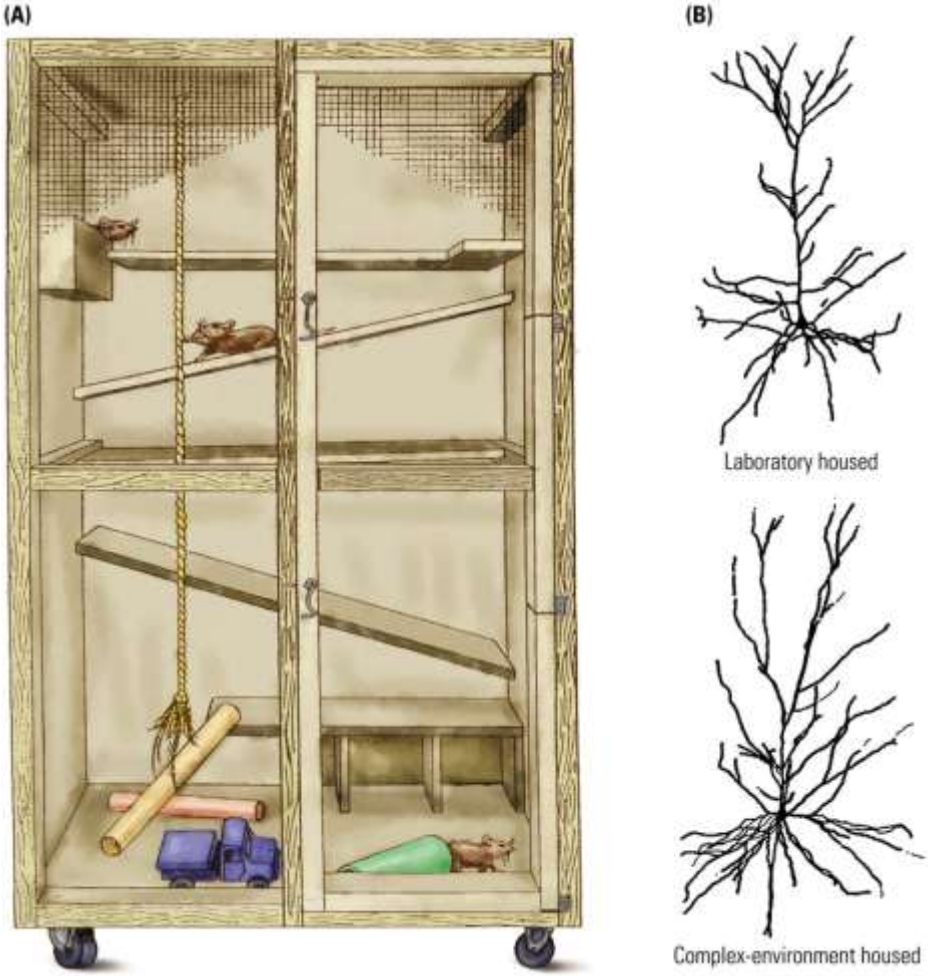
3. Drugs change neuronal networks in development

- **Amphetamine**
- **Caffeine**$^{+}$
- **Morphine**
- **Antidepressants** $^{+}$
- **Alcohol**$^{+}$
- **Antipsychotics**$^{+}$
- **Anxiolytics**$^{+}$
- **Nicotine**$^{+}$
- **Methylphenidate**

And they have long-lasting effects…

- Later plasticity is altered or blocked…



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But early experience can modulate later drug effects

- E.G.: pre- and postnatal tactile stimulation reduces later effects of drugs in adulthood

4. Parent-infant interactions

- Parent-infant interactions alter brain

Consequences?

- **The caregivers' behaviour affects the lifelong health of the infants by altering brain development and later stress reactivity.**

This is transferred to the infants in an epigenetic manner

Animal models of parental care

- Degus have biparental care

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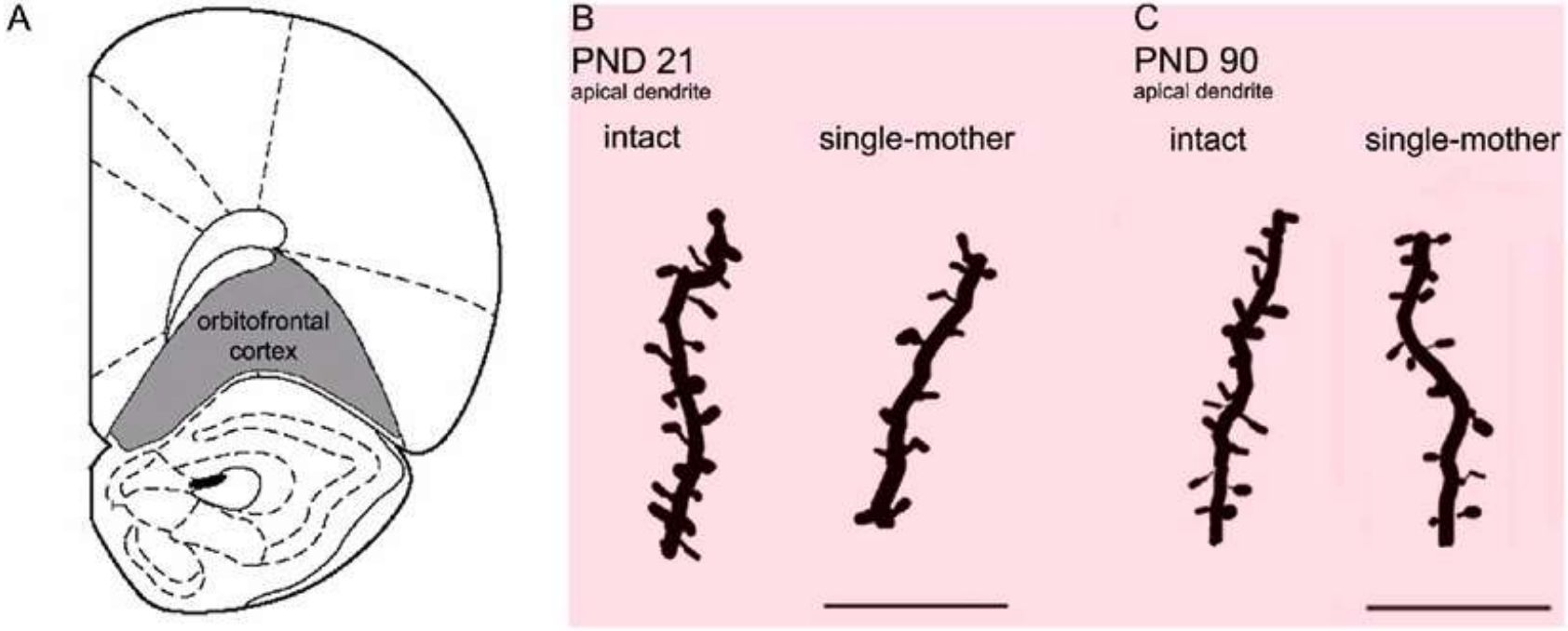
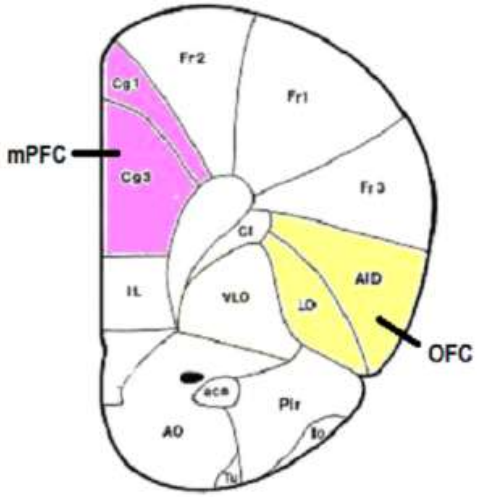
Single parenting alters the frontal lobe in degus

Helmeke et al., Neuroscience 163 (2009) 790–798.



5. Early stress alters frontal lobe development too

- Smaller brains
- Impaired cognitive, motor & social behaviour



The Bystander Stress Story

- Richelle Mychasiuk's study…

The Bystander Stress Story

- **21,864 genes in rat genome**
- **about 115 genes show large changes in expression**
- **many of these genes are related to synaptic reorganziation**

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So what?

- **The changed structure of the frontal regions means that they will function differently…**

- **AND that they will respond to other experiences differently**

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6. Play is important to brain development

All mammals play with clear rules…

There are species differences in adult social behaviour that can be seen in trajectories of the development of play behaviour & reflect genetic effects…

Macaca fuscata

Macaca tonkeana

Tonkeans are more placid and have much more active play behaviour

Rheinhart & Pellis, in progress

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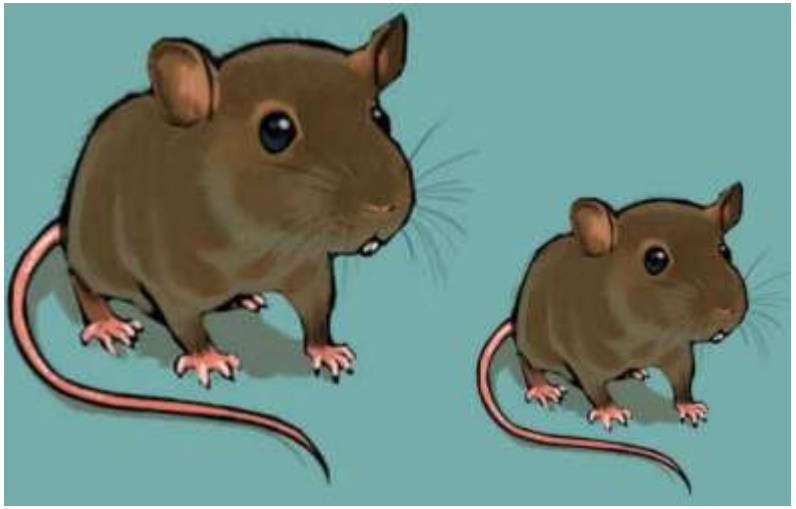
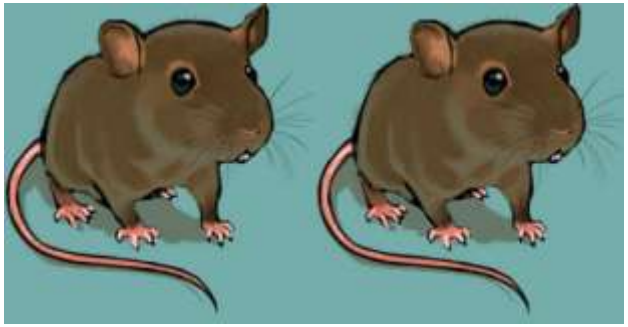
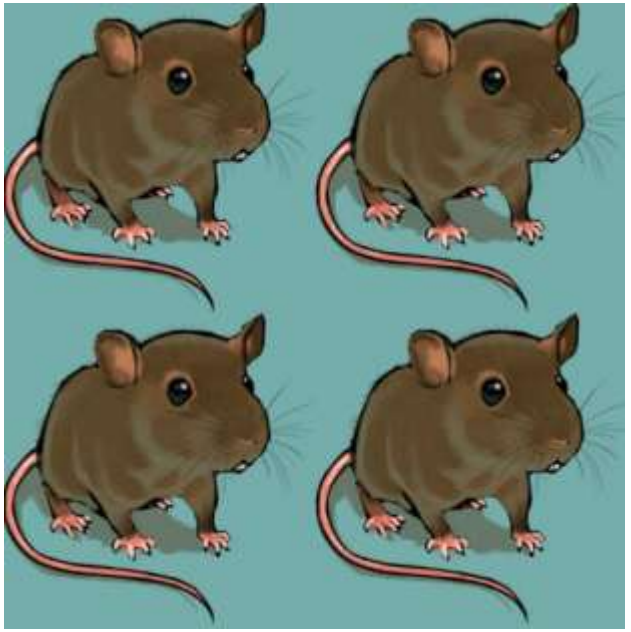
Amount & nature of play behaviour is manipulated







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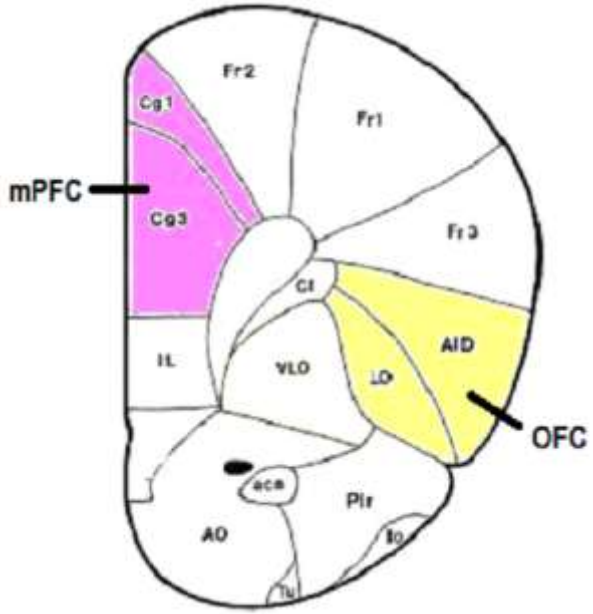
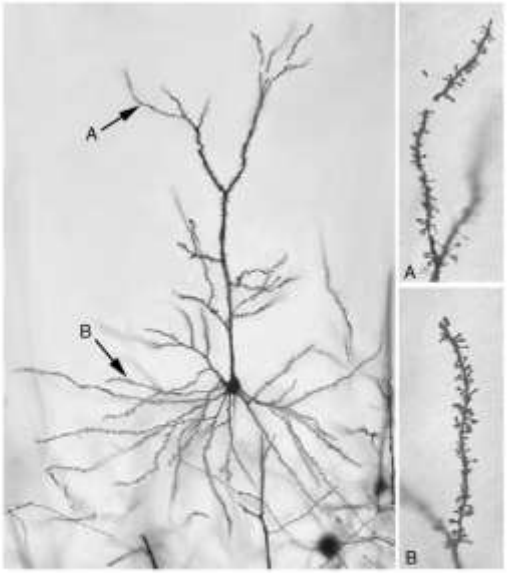
Play alters frontal lobe development

- **Sibling play = more complex mPFC**
- **Conspecific number = more complex OFC**





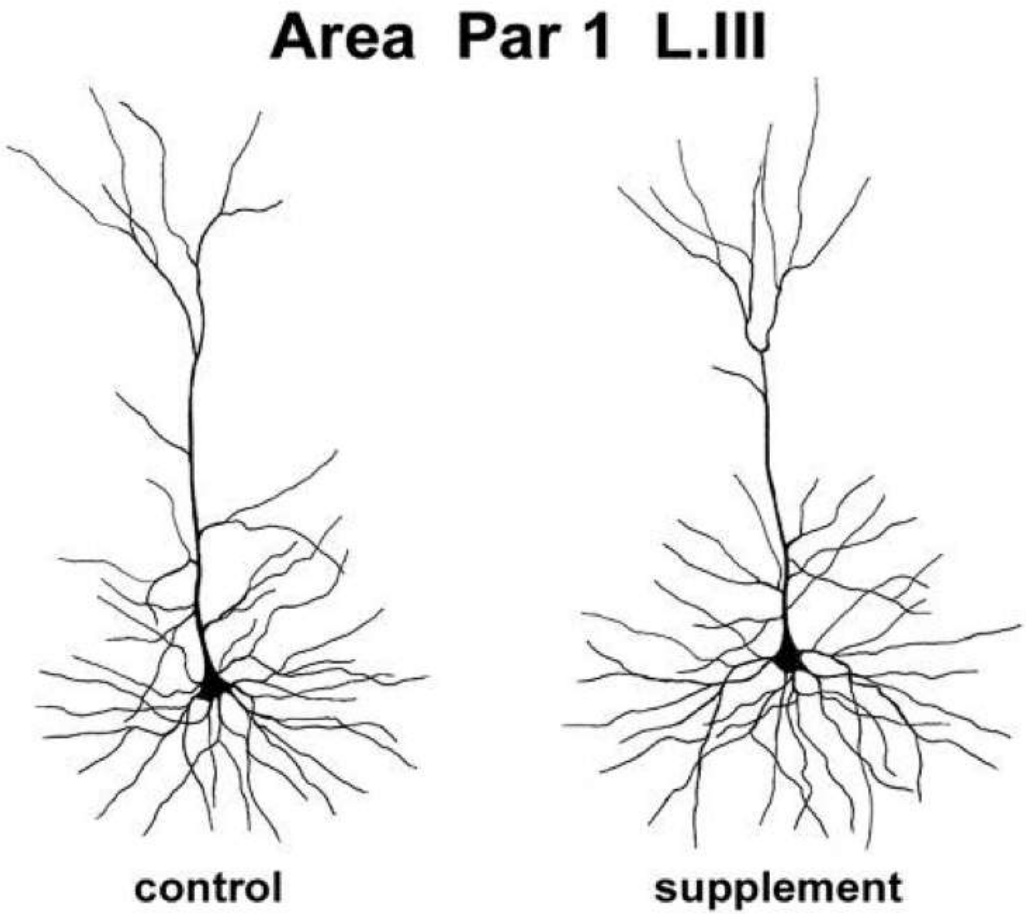
Is this important?

Think about human conditions such as autism, ADHD, and so on - they alter play behaviour.

What about 'normal' children who do not have an opportunity for regular play?

What is this doing to brain & cognitive development?

7. Diet alters brain organization



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Conclusions

1. Brain & cognitive development is prolonged and influenced by a wide range of factors.
2. Perinatal events can have important implications for understanding adult brain and behaviour relationships.
3. Epigenetic changes are just beginning to be understood related to brain plasticity.
4. Understanding the issues around brain plasticity and behaviour have important implications for public policy