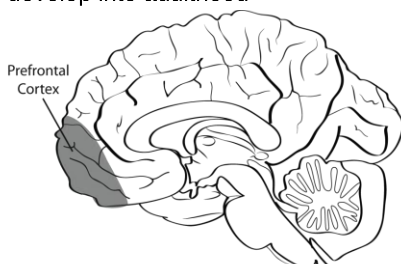
# Brain Development and Toxins
# PART 1 –The Neuroscience of Maturity

**Figure 1**: The Prefrontal Cortex, which is involved in decision making and impulse control continues to develop into adulthood




## Biology Brief: The Neuroscience of Maturity

Neuroscientists now have evidence that the brain is still developing, even into your 20's. Changes in your brain's anatomy and function are still taking place during young adulthood, especially in prefrontal regions that are important for planning ahead, anticipating the future consequences of decisions, controlling impulses, and comparing risk and reward (**Figure 1**). Should this new knowledge prompt us to rethink what we allow people do to at certain ages (**Table A**)?

**Table A:** Legal boundaries between minors and adults

| | Minimum Age |
|---|---|
| **Driving** | 14-16 |
| **Working** | 14-15 |
| **Informed Consent** | 16 |
| **Rated-R Movie** | 17 |
| **Smoking** | 18 |
| **Voting** | 18 |
| **Military Service** | 18 |
| **Marriage** | 18-21 |
| **Drinking Alcohol** | 21 |

Maybe, but it's not as straightforward as picking one age where someone finally "grows up." Different brain regions mature at different times. There is no single age at which the adolescent brain becomes an adult brain. Brain systems responsible for logical reasoning usually mature by the time people are 16, but those involved in self-regulation are still developing in young adulthood. This is why 16-year-olds are just as able as adults to make decisions about their health care, but still immature about controlling their behavior. In fact, the Supreme Court has noted in several recent cases that a young person is less responsible than a 30 year old for his or her own criminal behavior. Using different ages for different legal boundaries would make the most neuroscientific sense.

But science has never had much of an influence on these sorts of decisions. If it did, we wouldn't have ended up with a society that permits teenagers to drive before they can see R-rated movies on their own, or go to war before they can buy beer. Surely the maturity required to operate a car or face combat is greater than the maturity required to handle sexy movies or to drink. Age boundaries are drawn for mainly political reasons, not scientific ones. It's unlikely that brain science will have much of an impact on these rules, no matter what the science says.

Adapted from "What the Brain Says About Maturity" (Laurence Steinberg, published in The New York Times May 28th, 2012)

### Discussion questions:

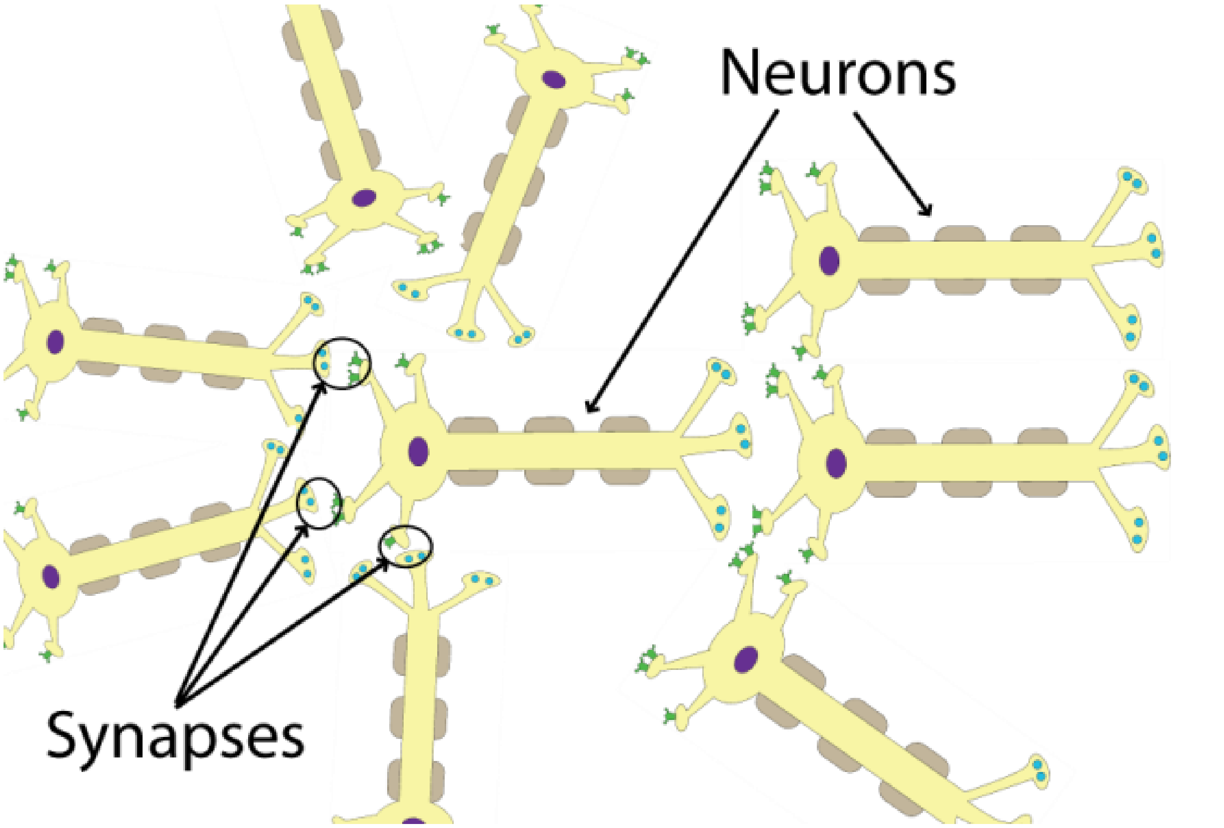
- Summarize what you learned from the article?
- Does the author believe that science should be used to make changes to the law? (Provide Evidence)
- At what age does the author suggest that the brain becomes fully mature?
- What are the advantages of using scientific findings to decide when you can and can't do things?

# PART 2 –Brain Development

**Biology Brief: Stages of Brain Development**

In the introductory activities you learned that one **neuron** can communicate with another neuron across a **synapse**. Your brain is complex and **one neuron in your brain may receive input from as many as 1000 other neurons** (**Figure 1**). The connections among the neurons in your brain determine how you think, feel, behave, and communicate.

**Figure 1**: Neurons in the brain form synapses with many other neurons.




Where did these connections come from? How are they made, kept or thrown away? Unlike skin cells and blood cells, which are replaced many times during your life, most of the neurons in your brain are formed before you are born and will last a lifetime.

**Activity- Card Sort**

Brain development begins before you're born and continues all the way to adulthood. **Table A** on the following page presents some of the key steps in brain development that occur before (pre-natal) and after birth (post-natal).

- Read the descriptions under the column titled "**Key changes**".
- Then place the **Brain Development Card** that you think best illustrates the key changes described in the table in the space to the right.
- When you are finished, answer the questions which follow the table.

**Table A: Stages of Brain Development (pre-natal = before birth, post-natal = after birth)**

| | Developmental Stage | Key changes | Select the illustration that best matches the key changes |
|---|---|---|---|
| Pre-Natal | 1-4 weeks | • Cells in the outer layer of the embryo begin to differentiate into brain cells (neurons). These early neurons separate from non-neural cells and begin to form the shape of the brain. | |
| | 5-12 weeks | • Brain cells go through mitosis (cell division) forming up to 100,000 new cells per second. By week 12 the developing brain has about 200,000,000,000 cells or about twice as many as an adult brain. | |
| | 13-40 weeks | • Brain cells begin to die through programmed cell death, called apoptosis resulting in a loss of about half (50%) of the cells that had formed by week 12. | |
| **Post-Natal** | **0-2 Years Old** | • When a baby is born, she has about 100 billion brain cells with short axons and few connections to other neurons. From birth to age 2, new synapses form at the rate of up to 2 million new synapses each second. By age 2, there are about 1 quadrillion synapses. This gives babies the ability and flexibility to learn things quickly. | |
| | **0-20+ Years Old** | • Beginning at birth nerve axons are wrapped with a coat of myelin insulation which helps to dramatically speed up the rate of neuron communication. This myelination process continues into early adulthood and contributes to increases in brain size. | |
| | **10-19 Years Old** | • By the time you are 20, your brain has about half the peak number of synapses you had at age 2. This reduction in synapses, called pruning, occurs in your teens. It makes your brain more organized and effective. You can make quicker and clearer decisions BUT it slows your ability to learn new things. | |

Refer to **Table A: Stages of Pre-Natal Brain Development** on the previous page to answer the following questions.

**Questions:**

1. Record the order of the illustrations by entering the letter code on each card in the to the right of the correct developmental stage in the column labeled **Illustration letter code.**

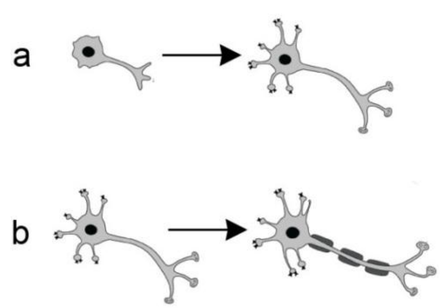
| | **Developmental Stage** | Illustration (letter code) |
|---|---|---|
| Pre-Natal | 1-4 weeks | |
| | 5-12 weeks | |
| | 13-40 weeks | |
| Post-Natal | 0-2 Years Old | |
| | 0-20+ Years Old | |
| | 10-19 Years Old | |

1. Complete the following sentences by circling or filling in the correct answer.
    - During adolescence synapses **increase / decrease** through the process known as _______________.

    Which of the illustrations/steps in "Table A: Stages of Brain Development" helped you answer this question?

    ___________________________________________________________________

    - In the following illustration, which most accurately represents the process of myelination:




Explain why you selected this choice.

___________________________________________________________________

___________________________________________________________________

2. Do you agree or disagree with the following statements. **Provide evidence.**
   a. Brain cells divide rapidly when a fetus is 5-12 weeks old. Agree or disagree? Explain your reason

      ______________________________________________

      ______________________________________________

   b. Cells in the pre-natal brain die due to old age. Agree or disagree? Explain your reason.

      ______________________________________________

      ______________________________________________

3. What might explain the large increase in brain weight that occurs in the first years of life? *(Circle one)*

   A. Increase in the number of neurons/cells in the brain through cell division

   B. Growth and myelination of existing neurons

   C. Changes in diet

   D. Increase in blood flow to the brain

<u>Apply what you've learned</u>

Ever since she was little, 40-year-old Rachel had always wanted to learn to play an instrument. When Rachel's 9-year-old daughter, Eva, started taking violin lessons she thought she would too.

Now Rachel was frustrated. Eva had just played the tune on her violin perfectly while she was still struggling to get the first part down. Rachel couldn't understand why it was so much harder for her to learn the same thing that her daughter was learning!

4. Based on what you know about the brain why do you think Rachel (age 40) may have a harder time learning to play an instrument than her daughter, Eva (age 9)?

   ______________________________________________

   ______________________________________________

# PART 3 –Brain Development and Toxins

**Biology Brief: Toxins and the Brain**
The brain is quite sensitive to **environmental toxins** for a number of reasons. For one the brain controls many biological processes so disruption of any part of the brain is likely to affect some aspect of life. Also because your brain doesn't regenerate easily, like blood and skin does, damage to the brain can be long lasting or permanent. Humans are especially sensitive before birth because the **blood-brain barrier**, which partly protects the brain from harmful chemicals and infections, is still developing and somewhat leaky. Also, the brain undergoes so many dramatic changes in size and shape before birth meaning toxins can disrupt major events in brain development.

Chemicals that can damage the brain are called **neurotoxins**. Neurotoxins can affect the brain in many ways. Some toxins affect specific stages of brain development while others can affect multiple stages of brain development. Some neurotoxins include: lead, found in paint dust and paint chips from homes built before 1978; alcohol, found in beer, wine and liquor; organophosphates (OR-GAN-OH-FOSS-FATES), found in insecticides; and even chronic stress, which can lead to long term changes in body hormones that can affect the brain.

**Answer the questions below based on the Biology Brief: Toxins and the Brain**

**Questions:**

1. What is a Neurotoxin?

   ______________________________________________________________

2. List three examples of neurotoxins

   i______________________________

   ii.______________________________

   iii.______________________________

3. At what stage of development is the brain most sensitive to toxins and why?

   ______________________________________________________________

   ______________________________________________________________

   ______________________________________________________________

**In this part you and your partner(s) will examine samples and case reports of patients with different symptoms. Your goal is to figure out what neurotoxins they may have been exposed to and what effects these neurotoxins can have on brain development**

# Lab Record

Instructions:

- Read the **Patient Reports**(s) and the **Neurotoxin Information Guide** carefully.

- Based on the patient symptoms and the information in the Neurotoxin Information Guide determine which toxin is most likely affecting your patient(s). This is your preliminary diagnosis, which is like a hypothesis.

- Record your preliminary diagnosis in the space below.

| Patient # | Preliminary Diagnosis |
|---|---|
| **1** | *Stress* |
| **2** | *Lead* |
| **3** | *Alcohol* |
| **4** | *Insecticide* |

- Determine which lab test(s) you wish to perform. You will need the following supplies:
  - Lab Test Instructions
  - Lab Test Sheet
  - Patient Sample(s)
  - Lab Test Supplies

- Follow the **Lab Test Instructions** carefully and enter in the results from the patient tests below.

**Lead**

| Patient Sample # | Lead Level |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |

**Alcohol**

| Patient Sample # | Alcohol Level |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |

**Cortisol (Toxic Stress)**

| Patient Sample # | Cortisol Level |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |

**Organophosphate Insecticide**

| Patient Sample # | Organophosphate (+/-) |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |

**Biology Brief: Treatments for Neurotoxin Exposures**

In the previous section you learned that the brain is sensitive to many neurotoxins and explored several examples. Exposure to a neurotoxin may require short term and long term treatment. In the short term treatment may be needed to remove the toxin and stabilize the patient to prevent death or disability. Over the long term, individuals may need ongoing support and therapy to help restore their brain function or to adapt to the effects of the damage.

**Lead Poisoning:**
Children diagnosed with lead poisoning are first treated with dimercaptosuccinic acid which binds to lead, prevents it from causing further damage, and helps eliminate it from the body. Children exposed to lead over a sustained period of time can often show problems with learning and memory. Research, originally performed in rats, indicates that providing these children with social supports like more stimulating learning environments can help reduce the effects of lead poisoning.

**Organophosphate Poisoning:**
Patients with organophosphate poisoning are usually given a drug like atropine which binds but does not activate neurotransmitter receptors on neurons. This prevents accumulated neurotransmitters from continuing to activate receiving neurons. Long term organophosphate poisoning has been linked to development of Parkinson's disease and dementia. Treatment for these long term effects may include a variety of medications that decrease the symptoms such as uncontrollable tremors.

**Alcohol Toxicity:**
Immediate treatment for ethanol intoxication is usually supportive and involves giving individuals intra-venous (IV) fluids until the body can break down the alcohol. In severe cases breathing and cardiac support may be needed to sustain life.

Cases of chronic alcohol abuse during adolescence can lead to Alcohol Use Disorder (AUD), resulting in a decreased ability in problem solving, verbal and non-verbal retrieval, visuospatial skills, and working memory. Treatment for individuals with AUD may involve various forms of psychotherapy, educational support and possibly medication.

Prenatal exposure to alcohol can lead to Fetal Alcohol Syndrome (FAS). Children with FAS cannot be cured but a supportive and nurturing environment can help improve the prognosis for these individuals.

**Chronic Stress:**
The effects of chronic stress are first treated by avoiding or at least decreasing the stressful conditions. Long term effects of chronic stress can be treated with counseling and anti-anxiety medicines and/or anti-depressants. Studies have shown that the combination of talk therapy (counseling) and medicines can help individuals to make dramatic improvements.

**Final Report**

- Identify the toxins that are responsible for the symptoms of each patient.
- Refer to the **Neurotoxin Information Guide** and the **Stages of Brain Development (Part 2)** to provide a possible explanation for the symptoms the patient is experiencing.

4. Complete the table below

| Patient # | Final Diagnosis |
|---|---|
| ***1*** | |
| ***2*** | |
| ***3*** | |
| ***4*** | |

5. Select one toxin and answer the questions below

a. Toxin: _________________

b. Explain how the toxin affects brain development.

________________________________________________________________________

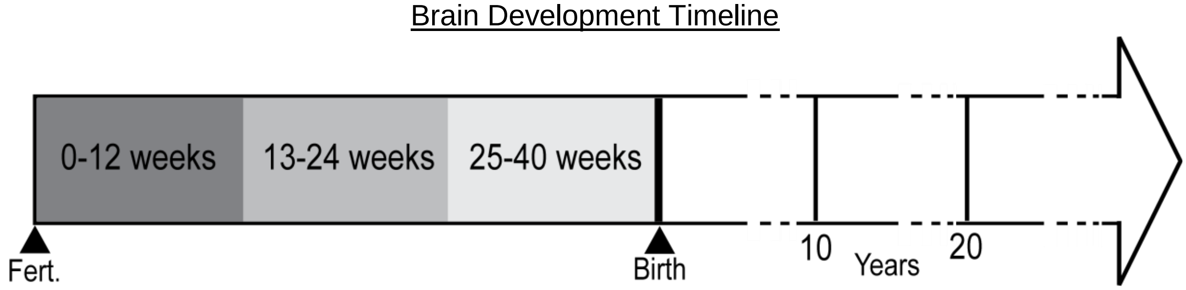
________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

c. Mark on the Brain Development Timeline below where the toxin(s) could have an effect. *You may mark more than one stage.*

Brain Development Timeline




d. What treatment(s) should be provided for a person exposed to this neurotoxin?

________________________________________________________________________

________________________________________________________________________

6. Which neurotoxin do you believe is the greatest threat to brain development and why? (You should consider how common the toxin is or how likely it is that someone could be exposed to the toxin.)

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________________________________________________________________

________________________________________________________________

________________________________________________________________