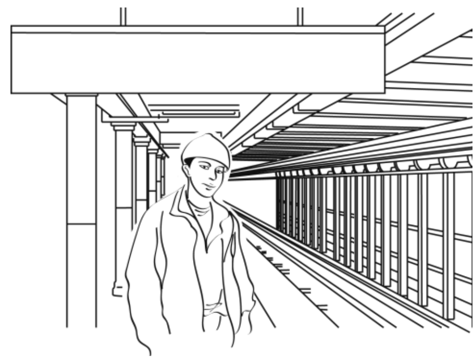
Part 1—Neuroscience of Risk

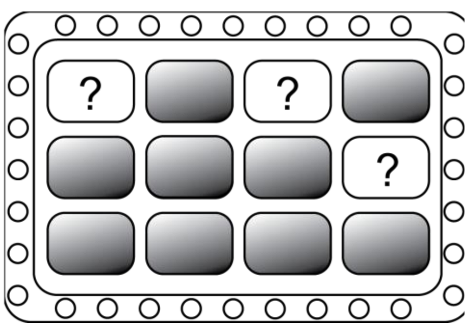
Biology Brief: Biology of Behavior

The term phenotype refers to the observable traits of an organism. It is the organism's phenotype which directly determines its chances of surviving and passing on its genes to the next generation. Some of the most familiar examples of phenotype include physical traits like eye and hair color, height, and blood type. However, traits may also include things that are less obvious like behaviors. One example of a behavioral trait is risk taking behavior illustrated in the story below.

Wesley Autrey, a New York City construction worker, was a national hero. He jumped in front of an oncoming subway train to save a fellow passenger. "I had to make a split-second decision," he told The New York Times the next day. "I just saw someone who needed help. I didn't really think about it. I just did what I felt was right."



Four months later, Wesley was a contestant on the hit NBC game show, Deal or No Deal. The show was essentially a guessing game. For each round of the game, contestants open several cases containing amounts of money ranging from one cent to one million dollars, removing those prizes from play.



Wesley, played fearlessly, and fared much better than most contestants. With only three cases remaining—$25, $10,000, and $1,000,000—he was offered a whopping $305,000 to walk away. When the host leaned in and whispered the show's pivotal question, "Deal … or no deal," Autrey answered: "No deal!" Instead, he called to eliminate case number 14. The amount inside: one million dollars! The audience groaned. Once again, Autrey was offered a buy-out—$5,000. But again he declined with a "No deal." When the next case he chose was removed it contained $10,000. The case he won contained only $25.

Adapted from "Let it Ride: The Neuroscience of Risk" by John Pearsonhttp://dukemagazine.duke.edu/dukemag/issues/111208/risk1.html

1. What are some **advantages** of being a risk taker? Or in what situations might it be beneficial to be a risk taker?

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2. What are some **disadvantages** of being a risk taker? Or in what situations might it be dangerous to be a risk taker?

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Biology Brief: Biology of Behavior (**continued)**

You may already know that genes, specific stretches of DNA that encode proteins, play a big role in determining physical traits like eye color and blood type. For example, a gene is **transcribed** into RNA which is then **translated** into a protein involved in melanin (pigment) formation which gives rise to a **phenotype** of black hair color (**Figure 1**).

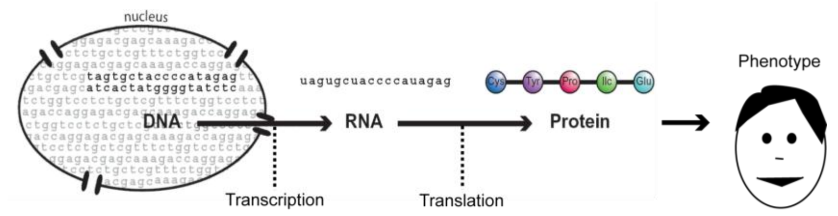

Figure 1: Physical traits like hair color are influenced by an organism's genotype. But what about behaviors? Are they also affected by genes?

What about behavioral traits like risk taking though? Are behaviors determined just by your **genotype** (an organism's particular set of genes) or are there other things that influence behavioral traits?

Questions

3. List two things other than genetics that might influence behavioral traits.

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4. Jeff has freckles and two copies (one from each parent) of the freckles gene (**homozygous**). Isaiah has freckles and one copy of the freckles gene and one copy of the non-freckles gene (**heterozygous**).

   These individuals have the same (*circle one*) **genotype / phenotype**
   but different (*circle one*) **genotypes / phenotypes**.

5. The process of making an RNA copy of a DNA code is called (*circle one)*

   a) Transcription
   b) Translation

6. The process of making protein based on an RNA code is called (*circle one*)

   a) Transcription
   b) Translation

Part 2: Personal Risk Taking Phenotype--Measurement 1

Complete the survey below. *(Circle the letter of the choice that best represents you)*

1. You often arrive:
    a. At the last minute or a little late
    b. Early

2. Do you like to ride roller coasters?
    a. Yes
    b. No

3. You think gambling and games of chance are:
    a. Fun
    b. Too risky

4. Would you like to travel to an underdeveloped country?
    a. Yes
    b. Not really

5. Would you like to ride a motorcycle, go whitewater rafting, bungee jumping, snowboarding, or scuba diving?
    a. Yes
    b. No

6. Getting lost in an unfamiliar place is:
    a. No big deal
    b. Scary

7. Your interests:
    a. Change every few months
    b. Are the same interests you've had for years

8. Do you do crazy things just for the fun of them?
    a. Yes
    b. No

9. Driving towards a stop light as it turns yellow you would:
    a. Speed up
    b. Slow Down

10. Would you say that you would try anything once?
    a. Sure
    b. No, not anything

Record the number of times you selected answer **a** or **b** below

# of times you answered “a”	# of times you answered “b”

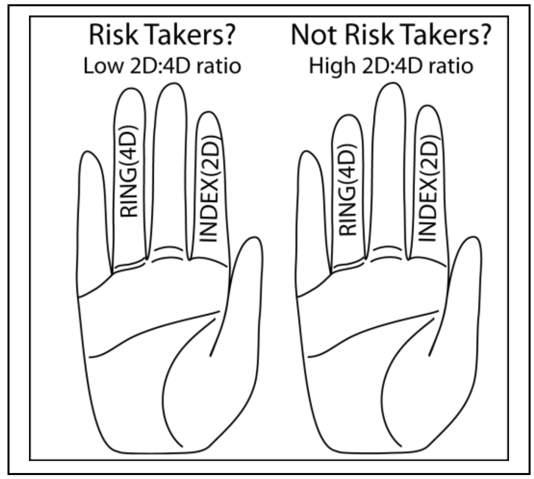
The more times you selected choice “a” the more likely you are a risk taker.

Part 3: Personal Risk Taking Phenotype--Measurement 2

Biology Brief: Pointing To Risk Taking

Some scientists claim that the length of the **index finger** (2^{nd} digit or 2D) when compared to the **ring finger** (4^{th} digit or 4D) correlates with risk taking behavior.

- If a person's 2D:4D ratio is **low,** (4D longer than 2D) they are more likely to be a risk taker.
- If a person's 2D:4D ratio is **high**, (4D equal to or shorter than 2D) they are less likely to be a risk taker.



Your class will collect data to test this claim. Each member of the class will determine his/her 2D:4D ratio. Then the class will create a scatter plot graph to determine if there is a correlation between their finger length ratio and their score on the risk taking survey.

To calculate the 2D:4D ratio you need to measure the length of the index finger (2D) in millimeters then divide this by the length of the ring finger (4D).

Shown below are two sample calculations:

$$\frac{73.6 \text{ mm (2D)}}{79.1 \text{ mm (4D)}} = 0.93 \quad \text{Low 2D:4D}$$

$$\frac{69.9 \text{ mm (2D)}}{71.3 \text{ mm (4D)}} = 0.98 \quad \text{High 2D:4D}$$

- Measure your 2D and 4D finger lengths.
  - **a)** Straighten the fingers on your **right hand** and look at the palm of your hand.
  - **b)** There are creases at the base of your index and ring finger. Your index finger is likely to have one crease. Your ring finger may have a band of creases.
  - **c)** Select the crease closest to the palm on your **2D (index finger)**
  - **d)** Use a pen to mark a spot that is in the middle of the crease.
  - **e)** Use a ruler to measure the distance from the spot to the tip of your index finger. Record your **2D** measurement in **millimeters**.

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  - **f)** Repeat steps c) through e) using your **4D (ring)** finger. Record your **4D** measurement in **millimeters**.

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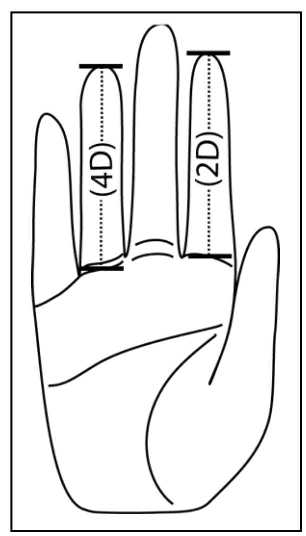

- Calculate your 2D:4D ratio by dividing the length of your index finger (2D) by the length of your ring finger (4D). Record your 2D:4D ratio on the line below.

$$\text{2D:4D ratio} = \frac{\text{2D measurement}}{\text{4D measurement}} = \_\_\_\_\_\_\_\_\_\_\_\_$$

- Write your 2D:4D ratio and your score on the Risk Taking Survey (number of a's) on a Post-It note.

- Place your Post-It note in the appropriate position on <u>one</u> of the graphs (male or female) that your teacher has provided in the classroom.

Questions

1. Observe <u>both</u> of the class Post-It note graphs. Summarize your observations of both graphs using complete sentences.

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2. Does the data on the graphs support the scientists' claim that there is a correlation between low 2D:4D ratio and high risk taking behavior? Why or why not?

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Part 4: Testosterone Signaling in Finger Development

Biology Brief: Testosterone Signaling Basics

Scientists have proposed that the 2D:4D ratio is determined during **prenatal** (before birth) development. The 2D:4D ratio results from interactions between:

- Levels of prenatal testosterone
- Testosterone receptors on the ring finger and index finger.

Testosterone is a hormone that is secreted by endocrine glands in the body. In the developing hand, testosterone acts as one of multiple different signals that cause cells to divide (**Figure 1**). It does this by binding to the testosterone receptors located in cells within the developing fingers. The testosterone receptors can then enter the nucleus and activate other genes that encode proteins which promote mitosis.

The more testosterone receptors a cell has, the more likely it is to respond to testosterone. Interestingly…there are usually more testosterone receptors in the ring finger than there are in the index finger, which helps explain the fact that the ring finger is typically longer than the index finger (**Figure 2**).

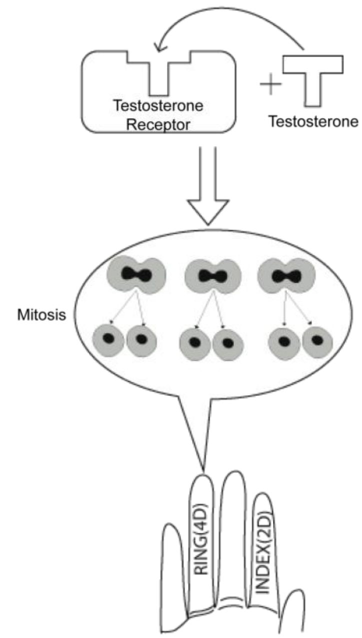

Figure 1: Testosterone binding to testosterone receptors in finger cells can promote cell division.

Because females tend to produce less testosterone during prenatal development compared to males, females' ring finger length is typically closer to their index finger leading to a higher 2D:4D ratio (**Figure 2**).

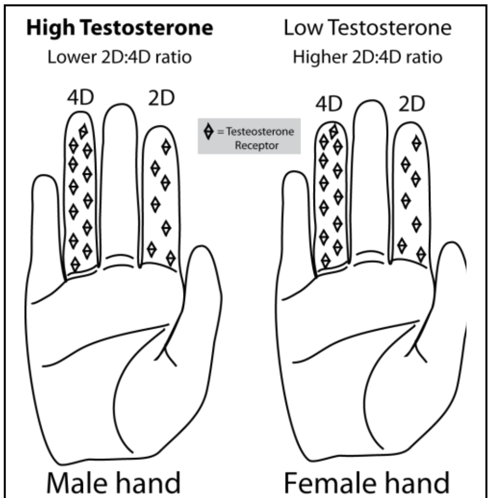

Figure 2: The 4D has more testosterone receptors than the 2D. Males have more testosterone than females. The combination of hormone level and receptor level leads to differences in 2D:4D ratio between males and females

NOTE: Prenatal testosterone levels are not related to adolescent or adult levels of testosterone.

Questions

1. Why do females typically have a higher 2D:4D ratio than males?

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2. What are two possible explanations for why different males might have different 2D:4D ratios.

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Part 5: Testosterone Receptor Genetics

Biology Brief: More about Testosterone Receptors

The testosterone receptor gene is located on the X chromosome. There are actually longer and shorter versions of the testosterone receptor gene (**Figure 1**). These longer and shorter genes encode longer and shorter versions of the Testosterone Receptor protein.

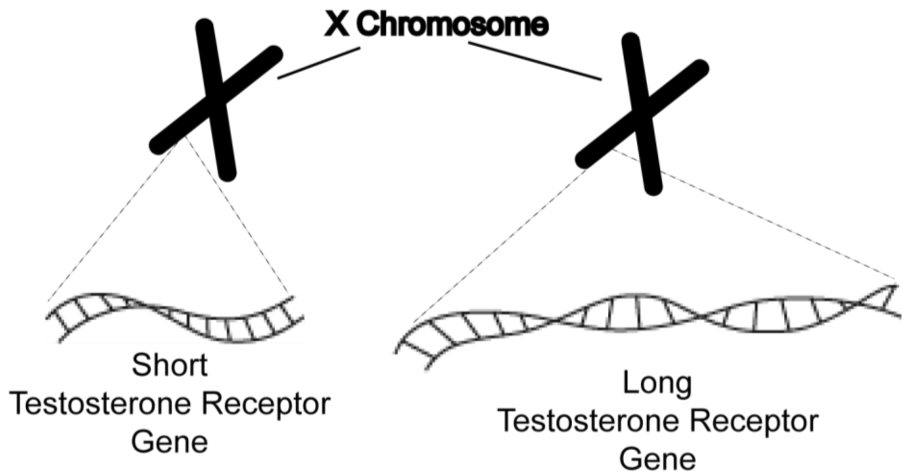

Figure 1: Individuals may inherit a shorter or longer version of the testosterone receptor gene.

For the information in the gene to be used, it needs to be transcribed into RNA and then the RNA must be translated into protein. Each group of three RNA nucleotides (which include A, U, C, or G) is called a codon. Codons specify which amino acids will be added next during protein synthesis (**Figure 2**). Amino acids are the building blocks of proteins.

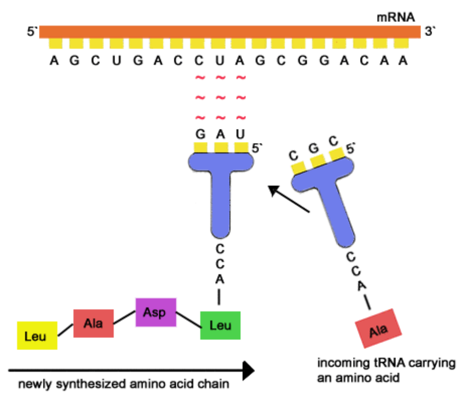

Figure 2: The amino acids (ex. Leu, Ala) are assembled into proteins by following the code contained in the RNA.

Activity--Crack the Code

- Examine the two testosterone receptor RNA sequences on the next page.
- Use **Table 1** to determine the amino acid sequence of the proteins encoded by the two sequences. For instance, if the first codon (set of three RNA nucleotides) is UUU this would encode Phenylalanine (Phe).
- Wherever you see a "STOP" that means that no more amino acids are added.

Table 1: The Genetic Code.

Second Letter

1st letter		U		C		A		G		3rd letter
	U	UUU	Phe	UCU		UAU	Tyr	UGU	Cys	U
		UUC		UCC	Ser	UAC		UGC		C
		UUA	Leu	UCA		UAA	Stop	UGA	Stop	A
		UUG		UCG		UAG	Stop	UGG	Trp	G
1st	C	CUU		CCU		CAU	His	CGU		U
		CUC	Leu	CCC	Pro	CAC		CGC	Arg	C
		CUA		CCA		CAA	Gln	CGA		A
		CUG		CCG		CAG		CGG		G
letter	A	AUU		ACU		AAU	Asn	AGU	Ser	U
		AUC	Ile	ACC	Thr	AAC		AGC		C
		AUA		ACA		AAA	Lys	AGA	Arg	A
		AUG	Met	ACG		AAG		AGG		G
	G	GUU		GCU		GAU	Asp	GGU		U
		GUC	Val	GCC	Ala	GAC		GGC	Gly	C
		GUA		GCA		GAA	Glu	GGA		A
		GUG		GCG		GAG		GGG		G

3rd lette

Testosterone Receptor Gene 1- **mRNA**
… … AUG UUC CGU GGU GAG CAG CAG CAA CAG CAA UAA GAA … …

Amino acid sequence encoded by Testosterone Receptor Gene 1:
(*write the sequence here*)

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Testosterone Receptor Gene 2- **mRNA**
… … AUG UUC CGU GGU GAG CAG CAG UAA GAA CCC GCA CGA … …

Amino acid sequence encoded by Testosterone Receptor Gene 2:
(*write the sequence here*)

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Questions

1. How are the two testosterone proteins' amino acid sequences the same or different?

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2. How many copies of the testosterone receptor gene would a male have?

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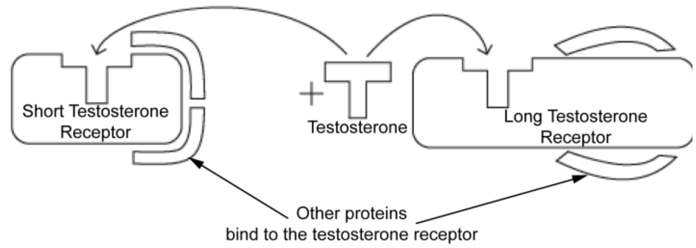
Biology Brief: More about Testosterone Receptors

You found out that the two different testosterone receptor genes code for short and long testosterone receptor proteins. A shorter amino acid sequence can have big consequences for a protein's shape. And the shape is what determines the functional ability of the protein.

Figure 3: The short testosterone receptor can interact better with other proteins in the cell.



Scientists have found that the shorter version of the receptor protein is better able to interact with other proteins in cells (**Figure 3**). By interacting better with other proteins, the short testosterone receptor is better able to trigger the cell responses to testosterone signaling.

Questions

3. What factor(s) can affect how a protein functions?

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4. Devon and David are both taking equal amounts of testosterone to treat a medical condition of low testosterone. Devon is responding better and more quickly than David to the testosterone treatment. Genetic tests were done of Devon and David to examine their testosterone receptor genes.

   Predict whether Devon most likely has the long or short version of the testosterone receptor gene and explain your answer.

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Part 6: From Protein Function to Behavioral Trait

Biology Brief: The Long and Short of Risk Taking

The parts of the brain involved in risk taking behavior may develop differently in people who have different length testosterone receptors. Risk taking is controlled by the reward system of the brain. The reward system of the brain includes the limbic system which controls emotions like happiness and the frontal cortex which controls decision making. In the brain, testosterone signaling can lead to increased connections between the limbic system and frontal cortex by promoting growth and mitosis of neurons connecting these regions (**Figure 1**).

Scientists have found that those who have shorter testosterone receptor proteins respond more strongly to testosterone while those with longer testosterone receptor proteins respond more weakly to testosterone (**Figure 1**). This means that people with the shorter, more active testosterone receptors are more likely to develop strong neural connections and increased activity in the brain's reward pathway.

Strong connections in the reward pathway may provide individuals with more positive feelings following a reward and increase their willingness to take risks to activate this region of the brain. Consistent with this idea scientists have used live brain imaging techniques to show that people with more active reward systems are more likely to take risks.

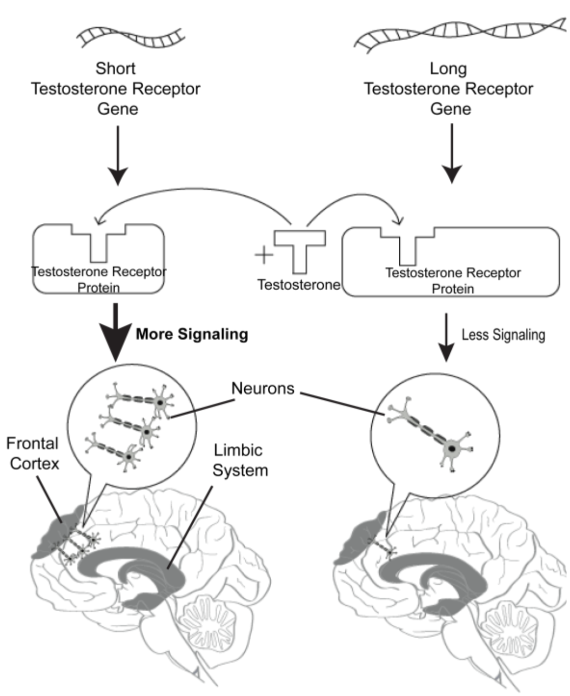

Figure 1: The short testosterone receptor, encoded by the shorter gene, sends a stronger signal in response to testosterone binding compared to the long testosterone receptor. More signaling leads to more connections in the limbic system and frontal cortex, which form the reward system of the brain.

Questions

1. What is the function of the testosterone receptor gene? (Refer to **Figure 1**)

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2. What is the function of the testosterone receptor protein?

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3. What regions of the brain are involved in the reward pathway?

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4. Hypothesize---Which gene (long or short) is more likely to result in an increased tendency for risk taking behavior?

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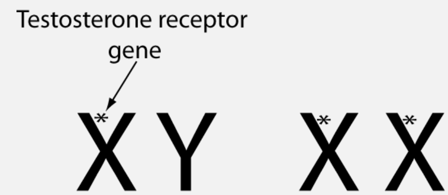
Activity--Test Your Hypothesis

Your lab kit contains a series of cards describing 10 male research subjects.

- Sort the cards into two piles—5 subjects who have a greater tendency for risk taking and 5 subjects that have lower tendency for risk taking.



Note: Male subjects (XY) were selected because the gene for testosterone receptor protein is on the X chromosome. That means that males only have one gene for the testosterone receptor protein.

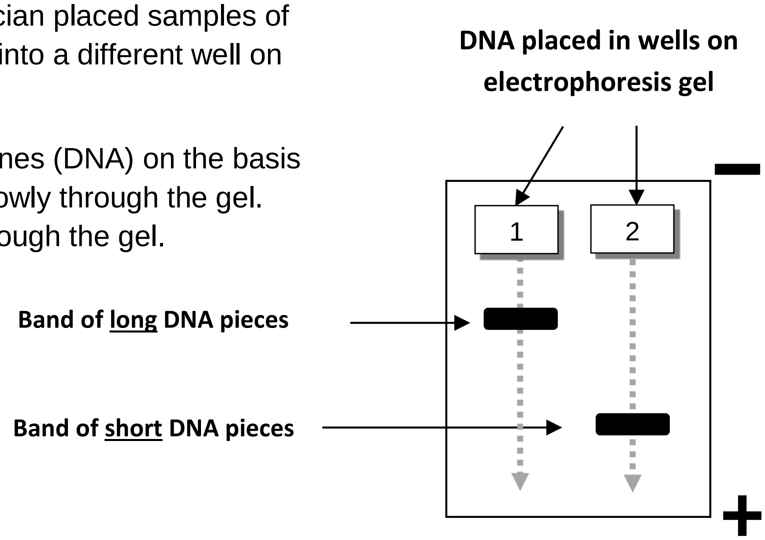
Question

6. The cards have numbers in the upper left-hand corner. Circle the numbers below that are in your "high risk taking" pile.

1 2 3 4 5 6 7 8 9 10

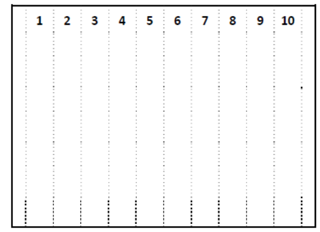
To test the receptor protein gene (DNA) samples for the ten research subjects, a lab technician placed samples of the gene (DNA) from each subject into a different well on an electrophoresis gel.

Gel electrophoresis separates genes (DNA) on the basis of size. Long DNA pieces move slowly through the gel. Short DNA pieces move rapidly through the gel.



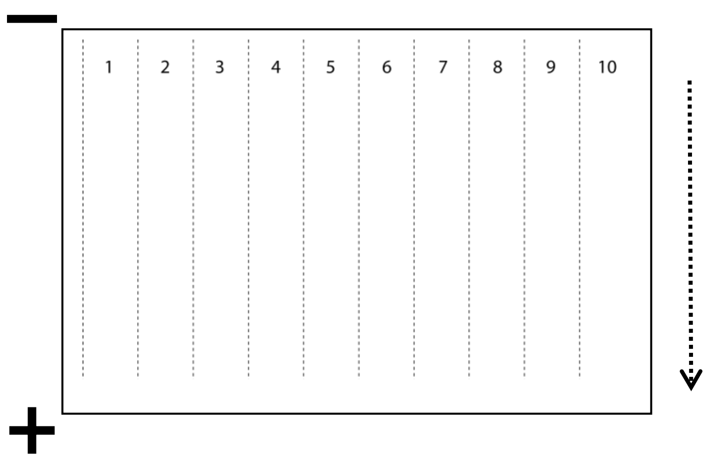
7. Which pattern of bands (1 or 2 in the graphic above) would represent a male with a short gene associated with risk taking behavior? ________________

Your lab kit contains a simulated paper electrophoresis gel that the lab technician made for the research subjects.



You can't see the DNA pieces on this gel because DNA is colorless. **To see the gene pieces, you need to will add a DNA stain to the gel.** This stain will attach to the genes on the gel and turn them pink.

- Add enough water to the plastic tray to completely cover the bottom with approximately 3 millimeters of water.
- Pour the entire contents of the tube of **DNA stain** into the water in the plastic tray.
- Use the stirrer to mix the DNA stain until it dissolves.
- Soak the simulated gel in the DNA stain in the tray for approximately 30 seconds.
- Observe the pink DNA bands on the gel. **Record the banding pattern on the diagram of the electrophoresis gel below.**



8. Circle the wells which contained DNA (genes) for the short testosterone receptor gene?

   1 2 3 4 5 6 7 8 9 10

9. Based on the results of DNA electrophoresis gel, can you conclude that the short testosterone receptor gene results in risk taking behavior? Support your answer with evidence from the gel. *Hint: Compare your answer for question 8 with your answer for question 6.*

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Part 7: Are there other factors that affect risk taking behavior?

Biology Brief: The Age of Risk Taking

Age is one factor that may affect risk taking behavior. Teenagers and adults were placed into a Magnetic Resonance Imager (MRI), which can measure activity in specific regions of the brain. Their brain activity was then measured while playing a gambling game which paid them small rewards for correct guesses. When the adults and teens won, the researchers recorded the activity in the right and left sides of the **cerebral cortex**, the highly folded outermost part of the brain involved in higher thinking and decision making (**Figure 1**).

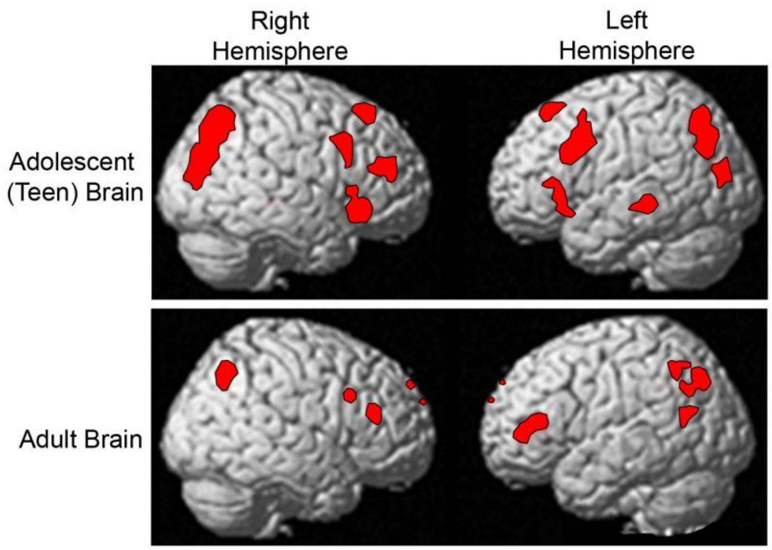

Figure 1: Post reward imaging of adult and teen brain activity (shaded regions).

Questions:

1. Describe any similarities or differences you observe in the images above.

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2. What is the name of the outermost brain region involved in decision making?

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3. Researchers believe that higher brain activity in some of these regions indicates more intense feelings of satisfaction. Knowing this how do you think this would affect teens or adults risk taking tendencies?

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Biology Brief: Environmental Factors and Risk Taking

Doing experiments in humans related to risk taking behavior is difficult for many reasons but a major challenge is that most individuals may have different genetic backgrounds and/or experiences (environmental factors) that can be difficult or impossible to control. To avoid the complications of human studies, scientists often use other model animals. One species being used to study the genetic and environmental factors that affect risk taking is the stickleback fish (**Figure 1**).

Figure 1: Stickleback fish are small freshwater fish that can be used to study animal behaviors like risk taking.
Image courtesy of http://fish.dnr.cornell.edu/nyfish/Gasterosteidae/stickleback.html

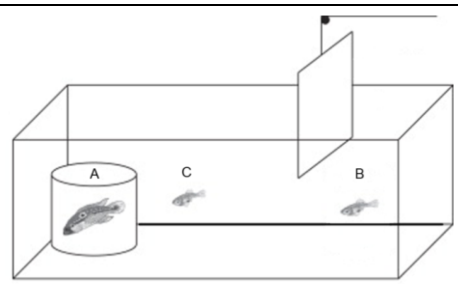

Figure 2: The test fish (C) will inspect the predator (A) more often when in the presence of another larger stickleback (B).

One example of risk taking behavior in sticklebacks is approaching and inspecting a predator decoy (an object shaped like a predator). When alone in a tank, small sticklebacks rarely take the risk of inspecting the predator model. However, when these same fish are paired with another larger stickleback they show much greater risk taking behavior (**Figure 2**). Interestingly, they do not inspect the predator as often when paired with another small stickleback.

Scientists believe that these studies may provide a model to understand how humans behave when acting alone or in groups.

1. Why might scientists use model animals, instead of humans, for research on risk taking behavior?

   ____

2. What is one environmental factor that increases stickleback risk taking behavior?

   ____

3. What are two examples of experiences or environmental factors that might affect human risk taking behavior?

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   ____

Optional short essay or class discussion question

Using information from this activity, which of the following do you think might explain people's risk-taking tendencies? Explain your answer.

- Genetic (inherited) differences
- Age-related changes in the brain
- Environmental influences