

MODULE 5: Gene Expression

7TH & 10TH GRADE

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INTRODUCTION

The Genomic Logic for Underlying Morphological Divergence (EPSCoR) project aims to bring

science-related learning experiences to schools. This lesson is the last of five designed to

facilitate learning about the concepts of natural selection (lesson 1), adaptation (lesson 2),

evolution (lesson 3), heredity (lesson 4) and gene expression (lesson 5). These lessons will

serve as a tool for the trainer or professional in charge of teaching (teacher, professor, among

others). For participants, they can be teachers (as part of their professional development) or

students.1

In this fifth lesson, the instructors or teachers of the Biological Sciences (7th grade) and Biology

(10th grade) courses, and their participants, will actively participate in some activities where they

will understand the concepts related to gene expression (genome and phenome).

This lesson includes:

✓ Scientific background of the concepts

✓ Glossary

✓ Alignment of the content to the standards, expectations, and specificities of the

Department of Education of Puerto Rico (DEPR)

√ Educational Process

✓ Detailed activities to carry out in the classroom.

SUBJECT: Science (Biological Sciences/Biology)

LEVEL: Intermediate - Advanced/ 7th – 10th grade

PRIMARY CONCEPTS: gene expression, genome, phenome

SECONDARY CONCEPTS: genetic variations, environmental conditions

PRIOR KNOWLEDGE: genes, alleles, inheritance, crosses, and probability

SPECIFIC LEARNING OBJECTIVES

Throughout the lesson, participants will:

DNA CAA A GAA A GA

- 1. define the concept of genome.
- 2. explain the difference between genomics and genetics.
- 3. describe what the Human Genome Project is.
- 4. summarize information about the technologies used for genetic mapping.

Continuous assessment

Throughout the activity, the instructor or teachers will be making observations while moving between the working groups, when participants discuss and when they present their answers to the questions. This allows the trainer to assess their learning.

STANDARDS, EXPECTATIONS AND SPECIFICITIES 7th GRADE - SCIENCE

Standard(s): Interactions and Energy

Area of expertise: Natural selection and adaptations

Expectation: B.CB4 Biological evolution: unity and diversity

Indicator

EI.B.CB4.IE.1 Discuss the impact of genetic engineering and biotechnology on agriculture, food production, and medical applications, among other areas.

EI.B.CB4.IE.2 Collects and summarizes information about technologies that have changed the way humans control the inheritance of desired traits in organisms. *The emphasis is on synthesizing information from reliable sources about the influence of humans on the genetic outcomes of artificial selection (such as genetic modification).*

Standard(s): Conservation and change

Area of expertise: Growth, development, and reproduction of organisms

Expectation: B.CB3 Inheritance and variations in characteristics

Indicators

EI.B.CB3.CC.1 Explain why structural changes in genes (mutations) located on chromosomes can affect proteins and cause beneficial, harmful, or neutral changes in the structure and function of the organism.

EI.B.CB3.CC.5 Describe the structure of DNA and explain its importance in living beings.

STANDARDS, EXPECTATIONS AND SPECIFICITIES 10th GRADE - SCIENCE

Standard(s): Structure and levels of organization of matter

Area of expertise: Inheritance and variations in characteristics **Expectation:** B.CB3 Inheritance and variations in characteristics

Indicator

ES.B.CB3.EM.1 Formulate questions to clarify the relationship between the role of DNA and chromosomes in encoding instructions for variations in characteristics that are passed from one generation to the next.

Standard(s): Conservation and change

Area of expertise: Inheritance and variations in characteristics

Expectation: B.CB3 Inheritance and variations in characteristics

Indicators

ES.B.CB3.CC.1 Formulate and defend an evidence-based statement that genetic and hereditary variations can result from: (1) new genetic combinations through the process of meiosis, (2) viable errors that can occur during DNA replication, and/or (3) mutations caused by environmental factors. The emphasis is on using data to support arguments about the different ways in which mutations can occur.

ES.B.CB3.CC.3 Recognize and explain that multicellular organisms develop from a single zygote and that the resulting phenotype will depend on the genotype that was established at the time of fertilization.

ES.B.CB3.CC.4 Explain the importance of continuity of life through the action of genes, hereditary patterns, reproduction in organisms, and cell reproduction.

BACKGROUND

Genome is a word used to refer to all your DNA. Every organism, from plants to dogs to bacteria, has their own genome. Each genome contains the necessary information to construct and maintain that organism all its life. For example, the human genome contains approximately 3 billion pairs of nitrogenated bases, which are found in the 23 pairs of chromosomes inside the nucleus of all our cells. Each chromosome contains hundreds of thousands of genes, which have the instructions to make proteins.

Genomics refers to the study of the entire genome, of all the genes that are found in an organism, in contrast with genetics, which studies genes individually. A genome investigator studies DNA completely, all the sequences in an organism, and draws conclusions based upon this. While a geneticist can study the entire DNA of an organism but can also study a gene individually. For example, they could study a gene's genetics and its sequence. If you would like to study an organism's or a person's genomics, you could sequence all its genes and all its DNA and could find the differences and compare them with the genomes of other individuals (Lawrence C. Brody, Ph. D.)

It is important to establish the difference between the genotype and phenotype of an organism. "Phenotype" refers to an observable trait. Phenotype simply means "to observe"; as such, it is something that is observable in an organism, and it may refer to anything from a common trait to height or hair color, or the presence or absence of an illness. Frequently, phenotypes are related and are used —the term is utilized —to relate a difference in DNA sequence among individuals with a difference in a trait, be it height, hair color, an illness, or anything. But it is important to remember that phenotypes are equally, or sometimes even mostly, influenced by environmental factors rather than by genetic effects. So, a phenotype can be directly related to a genotype, but not necessarily. Generally, there is a one-to-one correlation between a genotype and a phenotype. Almost always, there are environmental factors, like what one eats, whether one exercises or not, how much one smokes, etc. All of those are environmental influences that also affect the phenotype.

(Christopher P. Austin, M.D.)

Transcription is the process in which a DNA sequence is copied from a gene in the similar alphabet of RNA. It is important to highlight that **genetic expression** is the process whereby

all organisms, both prokaryotes and eukaryotes, transform the information coded by nucleic acids into the necessary proteins for their development, functioning and reproduction with other organisms. Unlike prokaryotes that only have one polymerase, eukaryotes have three distinct RNA polymerases. For this reason, each polymerase tends to recognize specific promoter sequences. Equally, regulation processes are more complex than in prokaryotes, including the position of DNA regulating sequences with respect to promoters. Promoters have defined nucleotide sequences, like "TATA" and "TTGACA" boxes. Promoters are localized at the beginning of the gene that will be transcribed, facing towards the 5' direction from the mold strand. Promoters have defined nucleotide sequences, like "TATA" and "TTGACA" boxes.

Lastly, we must keep in mind that the connection between gene expression and the organism's phenotype is that genes that are expressed are the ones that will be seen in the genotype. For example, if an organism has straight hair, it means that the trait for straight hair was the gene that expressed the type of hair.

GLOSSARY

- **DNA**; **deoxyribonucleic acid** molecule that stores the genetic information of all organisms.
- **DNA replication process—DNA** replication is the process through which a DNA molecule duplicates. When a cell divides, in the first place, it must duplicate its *genome* so that each daughter cell contains a full set of chromosomes.
- **Epigenetics** It is an emerging field of science that studies the hereditary changes caused by the activation and inactivation of genes without any change in the DNA sequence underlying the organism. "Epigenetics" is a word of Greek origin, and it literally means above (*epi*) the genome.
- **Gene expression**—the process by which the nucleotide sequence of a gene directs protein synthesis
- **Genome** It is the complete set of genetic material present in the cells of an organism.

 The genome refers to the total DNA of an organism.
- **Genomics** Branch of biology that analyzes the DNA sequence of specific organisms and compares it with other organisms with the objective of obtaining information about the specific role of genes. *Genomics refers to the study of an organism's complete genome, whereas genetics refers to the study of a gene.*
- **Genotype** Set of all coded traits in an organism's genetic information.

- **Human Genome Project** It was an international project that *identified* and sequenced all the human genes. The project ended in April 2003, and its data are freely available to researchers and others interested in genetics and human health.
- **Mapping** Process of elaborating schematic representations and cataloging genes and other chromosome traits, showing their relative location, also known as genetic cartography.
 - a. *Cytogenetic maps* are done via microphotographs of dyed chromosomes to reveal structural variations.
 - b. Genetic maps use the linkage technique to estimate the relative location of genes.
 - c. *Physical maps*, done through recombinant DNA (rDNA) technology, show the real physical location of reference points throughout a chromosome.
- **Mitochondrial DNA** It is a small circular chromosome that can be found in the mitochondrion. Mitochondria are cellular organelles where energy is produced.
- Mitochondria, and therefore mitochondrial DNA, can only be inherited from the mother.
- Non-coding DNA—Non-coding DNA sequences do not code for amino acids. Most of the non-coding DNA can be found between the genes in the chromosome and do not have any known role. Other non-coding DNA sequences, called introns, are found inside genes. Part of the non-coding DNA performs a role in the regulation of genetic expression.
 - d. Non-coding DNA is exactly that, DNA that does not code. You can think of the genome as if it were divided into two parts. A part codes for proteins, which we call codifying DNA, and the rest is the genome, which, due to lack of a better term, is named non-coding DNA. But it represents 98 percent of our genome sequence, and it does all kinds of things, like regulating our genes to know where they must activate or not, when they must activate certain genes, how DNA is packed in chromosomes, etc.
- **Nitrogenated bases** Organic compounds that include two or more nitrogen atoms.

 They are part of the nucleotides that form DNA and RNA molecules. Helix strands are interconnected between them by pairs of nitrogenated bases. The

- five main nitrogenated bases that we find in DNA and RNA are adenine (A), cytosine (C), guanine (G), thymine (T) and uracil (U, which is only present in RNA).
- **Nucleotide -** Organic compound (monomer) that forms DNA and RNA and that has a phosphate group, a sugar, and a nitrogenated base (see definition of nitrogenated bases).
- Operator It is the segment of the DNA that activates or deactivates genes.
- **Operon -** It is a region of the DNA that includes a promoter, an operator and one or more structural genes that synthesize all necessary proteins to realize a specific task.
- **Phenome** It refers to the traits that manifest in an organism. The phenome would be the complete set of phenotypical traits that manifest in an individual.
- **Phenotype -** Set of all physical traits of a determined organism that result from the interaction between its genotype and the environment.
- **Promoter** It is a segment of the DNA that permits the ARN polymerase enzyme to locate the point of start for the transcription.
- Recombinant DNA (rDNA) It is a technology that utilizes enzymes to cut and count DNA sequences of interest. Recombined DNA sequences can be placed in some vehicles called vectors that transport DNA to the adequate place of the host cell where it can be copied or expressed.

LEARNING PROCESS (BEGINNING, DEVELOPMENT, AND CLOSURE)

BEGINNING

During this part, the participants' prior knowledge about the concepts to be developed, which in this case are gene expression, genome, and phenome, will be explored. This permits the instructor to recognize misconceptions that the participants may have and ensure that they can correct them during the educational process.

1. The instructor will show the following diagram to sum up some branches of biology.

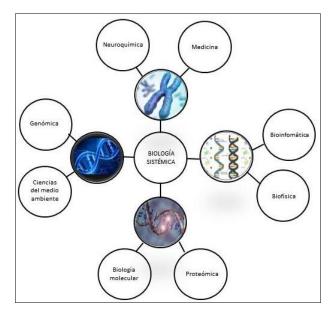


Diagram #1 Some Branches of Biology

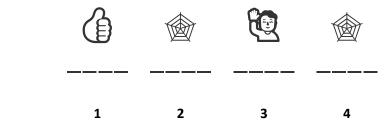
DEVELOPMENT

1) The instructor will hand out **Worksheet #1** so that participants, using codes, can decipher a message related to genomics.

Messages to decipher:

- Genomics analyzes DNA sequences of specific organisms and compares it to other organisms.
- The objective of genomics is to obtain information about the unique role of genes.
- c. An area of genomics called gene mapping lets us explain our genome's sequence.
- d. Plant genome sequencing gives scientists information about how to develop more productive crops.(See the key to look at the hidden messages).
- 2) The instructor will offer an example to explain activity #1.
 Example:

Hidden code



Deciphered code

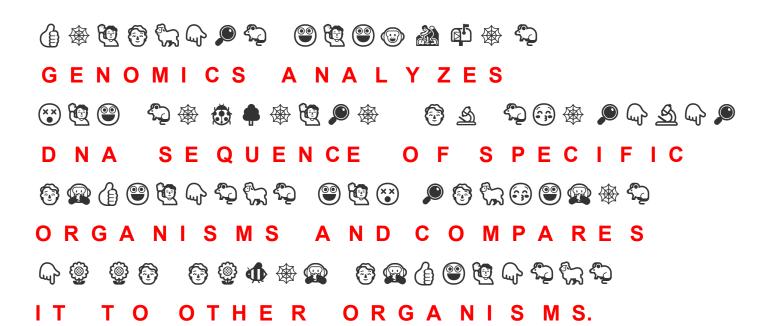
GENE

3) In cooperative groups, participants will complete Worksheet #1.

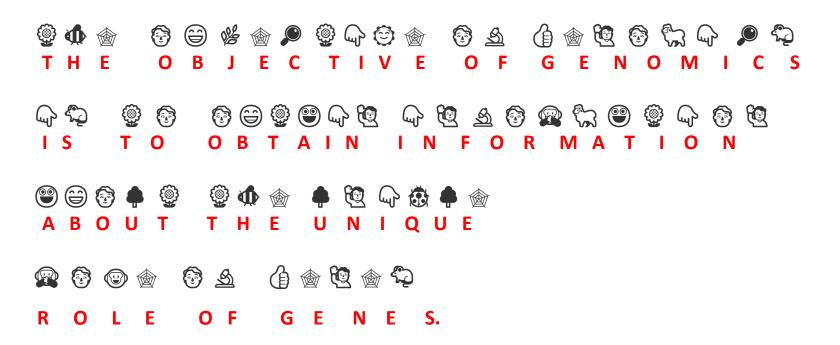
CLOSURE

- 1) In socialized discussion, each group of participants will read one of the deciphered messages.
- 2) The instructor could generate the following questions:
 - a. Taking into consideration what is discussed in the messages, what do you think that genomics is?
 - b. What do you think will be discussed in this lesson?

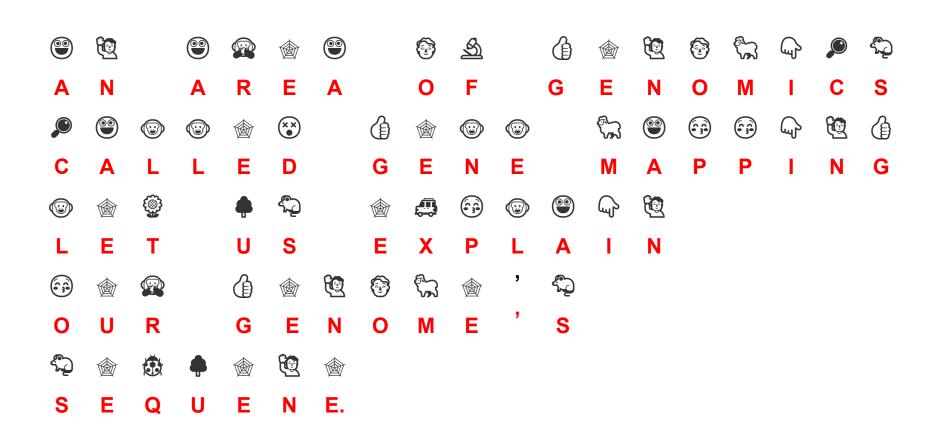
a. **Message #1:** Genomics analyzes DNA sequences of specific organisms and compares it to other organisms.



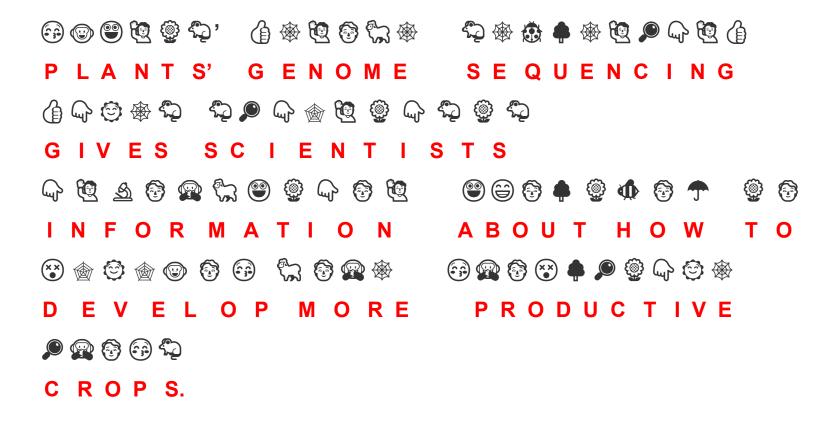
Message #2: The objective of genomics is to obtain information about the unique role of genes.



Message #3: An area of genomics called gene mapping let us explain our genome's sequence.



Message #4: Plants' genome sequencing gives scientists information about how to develop more productive crops.



Activity #1: Decipher the hidden message

Materials:

legend to decipher codes pencils or markers

Procedure:

- 1) Using the legend handed out by the instructor, decipher the hidden messages. Remember the instructor's example.
- 2) Complete the blank spaces so you can read the message.
- 3) Share the hidden message with your colleagues.

Using the legend, complete the blank spaces. Then, write the deciphered messages in the spaces below:

Message #1			
Message #2			
Message #3			
oodge #e			
Message #4			

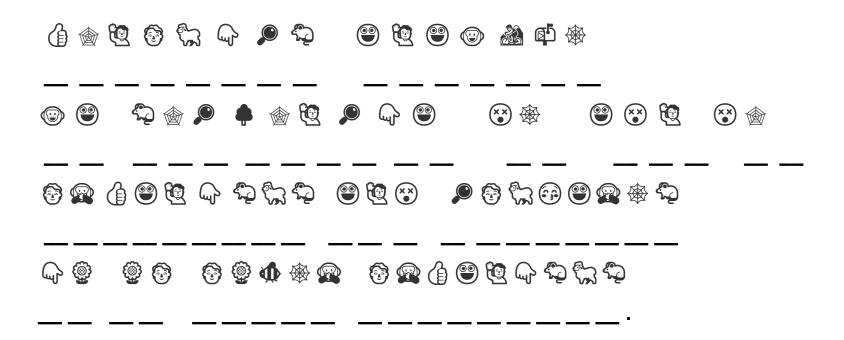
Use these codes to decipher the hidden messages.

Legend:

Letters	Symbols
A	
В	
С	
D	×× •
Е	
F	প্র
G	
Н	₩
I	(F
J	
K	
L	
M	

Letters	Symbols
N	
O	
P	
Q	
R	
S	٩
T	©
U	•
V	
W	T
X	
Y	
Z	a 5

Message #1

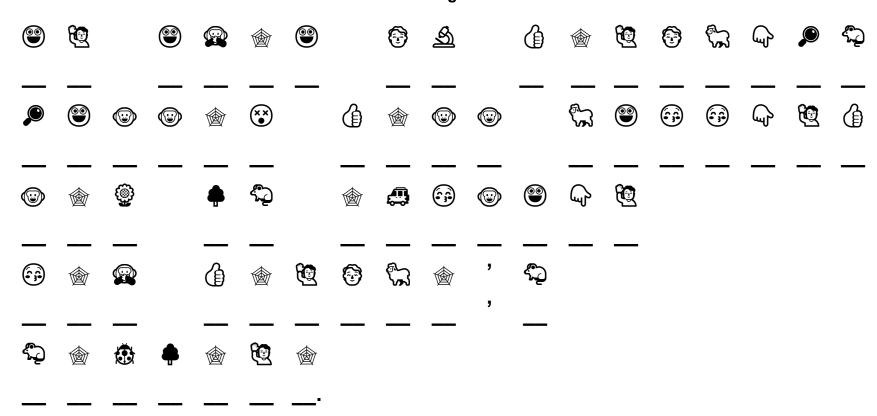


Activity #1: Decipher the hidden message.

Message #2

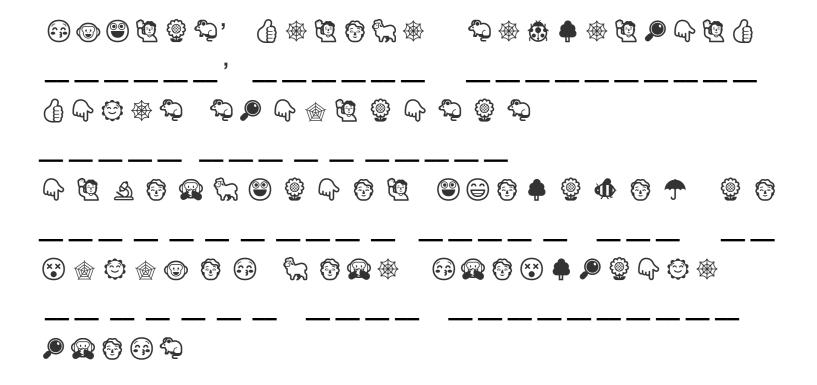


Message #3



Worksheet #1

Activity #1: Decipher the hidden message.



Activity #2: What is the genome?

BEGINNING

- 1) The instructor will show **figure #1** to the participants and will generate the following questions:
 - a. What do you observe in **figure #1**? **Expected answer:** silhouettes of people formed by letters can be observed (it is expected that they can recognize the nitrogenated bases A, T, G, C)
 - b. Can you establish a relationship between this activity and activity #1? **Expected answer:** In activity #1 we used symbols or codes to decipher a hidden message, and in this activity, we observed a sequence of different letters in each silhouette (some participants may comment that the letter sequences represent DNA).
 - c. What do these letter sequences represent? **Expected answer:** The letter sequences represent the DNA sequence.
 - d. Are all letter sequences (DNA) the same in all silhouettes? **Expected answer:** It is expected that participants answer that the letter sequences are not the same.
 - e. What does it imply to have all letter sequences in each silhouette to be different? **Expected answer:** That the DNA in each person is unique.
- 2) The instructor concludes and sums up the participants' expressions by indicating that this complete set of genetic material present in the cells of an organism is known as a genome.

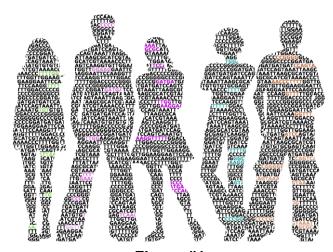


Figure #1

DEVELOPMNET

- 1) The instructor shows a video available at https://www.youtube.com/watch?v=ZmF2y3xM7Lk to explain in general what a genome is.
- 2) In cooperative groups, participants will work on **Worksheet #2**, where they will create a drawing, poster, or sketch in which they will explain what they understood about the concept of a *genome*.
 - a. The instructor will give general instructions to the participants to explain what the genome is and summarize what the genome is and what they learn with the video.
 - b. The instructor will indicate to the participants that the created works will be presented to the group.

CLOSURE

- 1) Each group of participants will explain their work.
- 2) The instructor will briefly summarize the presented ideas about the concept of the *genome* and will clarify doubts that may arise during the process.
 - a. The instructor will refer to the branch of biology (presented in activity #1) known as genomics, which refers to the study of the complete genome of an organism, while genetics refers to the study of a specific gene.

Activity # 2: What is the genome?

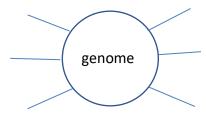
Materials:

video presented by the instructor cardboards or blank paper coloring pencils or markers

Procedure:

1.	Select the format of your work
	poster
	giant brochure
	concrete poem
	sketch
	concept map
	others:

2. Using the information in the video presented by the instructor, prepare a brainstorm to organize what you learned about the genome.



- 3. Prepare informative material to present to your colleagues about what you learned about the genome. Remember to create an appealing work in which you will summarize what the genome is.
- 4. Once the work is finished, you will present the materials to the rest of the groups.
 - **Remember**: your work must define what the genome is, present a drawing that explains what the genome is, and sum up what you learned with the video.

Activity #3: Knowing the genome of bacterial virus \$\phi\$X174

BEGINNING

- 1) In socialized discussion, the instructor starts by summarizing the previous activity. For example, we have already learned what the genome is and we know that all organisms have a different and unique DNA sequence (this introduction will help them understand the new activity). Use a PowerPoint presentation.
- 2) The instructor will ask the following question:
 - a) According to what has been learned about the genome, how do you think that genetic mapping is done?

Expected answer: It is expected that participants do not know how genetic mapping is done. Some may answer that it is done by analyzing DNA samples of an organism.

It is important to highlight that each DNA sequence may have millions of nitrogenated bases (remember that nitrogenated bases are joined by a phosphate group and a sugar – a five carbon sugar – to form different nucleotides), and as such, units like *kilobase* (10³) and *megabase* (10⁶) are used to make analyses.

3) The instructor shows **Figure 1**, of this activity in the PowerPoint presentation to abound about the definition of the concept nucleotide.

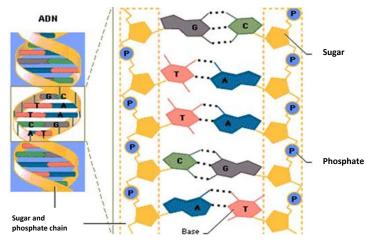


Figure 1

4) The instructor shows **Figure 2**, of this activity in the PowerPoint presentation for participants to observe that when analyzing DNA sequences, only the nitrogenated bases are written (remembering that they are part of the nucleotide). With this process it can be evidenced how technology facilitates the analysis of an organism's genome.

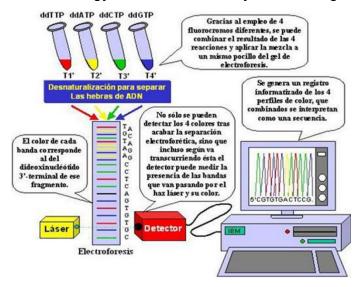


Figure 2

5) The instructor shows **Table #1 DNA Length for some organisms** to see how it varies in size (number of bases) between organisms.

Table #1 DNA Length for some Organisms

Taxon Organism		Pairs of nitrogenated bases (in 1000 or kb	Length
			-
Д 1] [
Dacteria	E. con (dei	760 4600	1.56 mm
Daotona	intestino humano)	1000	1.00 11111
Yeast		13 500	4.6 mm
Eukaryotes	Drosophila	165 000	5.6 mm
Lanaryotos	(mosca frutera)		
	Humans	2 900 000	99 cm

6) Once table #1 has been presented with the PowerPoint, the instructor will indicate to participants that activity #3 is an example of an organism and its analyzed genome.

DEVELOPMENT

1) The instructor will give an example of how to calculate the number of kilobases (kb) and megabases (Mb) using conversion factors. It is recommended to make an example of each one on the board or using the PowerPoint presentation. These examples will help complete activity #3.

Conversion factors

1kb = 1 kilobase = 1000 bases	1Mb = 1 megabase = 1000000 bases		
Example:	Example:		
If I have 2000 nitrogenated bases	If I have 2000 nitrogenated bases		
2000 bases	2000 bases		
1000 bases = 2.000 kb	= 0.0020 Mb 1000000 bases		

Results can also be expressed in scientific notation.

2) In cooperative groups, participants will complete **Worksheet #3**.

CLOSURE

- In socialized discussion, an explanation of analysis questions on Worksheet #3 will be made (see key for the questions).
- 2) It is important that, in this discussion, the instructor emphasizes that determining the number of nucleotides and, consequently, the DNA sequence of an organism is not easy. This process took years to develop, but as of today, technology lets us perform it quicker.
- 3) The Human Genome Project should be connected to the discussion. Today, technology exists that facilitates the determination of any organism's DNA sequence.
 - a. One of the areas of genomics, called genetic mapping, had its beginning with the mapping of a simple virus in 1977. Until today, scientists have mapped the genomes of hundreds of animals, like mice, frogs, and chimpanzees. The DNA sequence of our own genome was completed in 2003 as part of the Human Genome Project. This happened 26 years after the genetic mapping of a simple virus began. These technological advancements have let us know that the

human **genome** contains 3 billion pairs of bases, which **are found** in the 23 chromosome pairs inside the nucleus of all our cells. Each chromosome contains hundreds of thousands of genes, all of which have the instructions to make proteins.

Activity #3: Getting to know the genome of bacterial virus \$\psi X174\$

Materials:

Genome for the bacterial virus \$\phi\$X174

Table for the DNA Length for some Organisms

Procedure:

1) Analyzing the genome of the **bacterial virus \$\phiX174**, answer the analysis questions.

Genome of the bacterial virus \$\psi X174\$

1	GAGTTTTATC	GCTTCCATGA	CGCAGAAGTT	AACACTTTCG	GATATTTCTG	ATGAGTCGAA	
61	AAATTATCTT	GATAAAGCAG	GAATTACTAC	TGCTTGTTTA	CGAATTAAAT	CGAAGTGGAC	
121	TGCTGGCGGA	AA <mark>ATGAGAAA</mark>	ATTCGACCTA	TCCTTGCGCA	GCTCGAGAAG	CTCTTACTTT]
181	GCGACCTTTC	GCCATCAACT	AACGATTCTG	TCAAAAACTG	ACGCGTTGGA	TGAGGAGAAG	Gene #1
241	TGGCTTAATA	TGCTTGGCAC	GTTCGTCAAG	GACTGGTTTA	GATATGAGTC	ACATTTTGTT	F Gelle #1
301	CATGGTAGAG	ATTCTCTTGT	TGACATTTTA	AAAGAGCGTG	GATTACTATC	TGAGTCCGAT	
361	GCTGTTCAAC	CACTAATAGG	TAAGAAATCA	TGA GTCAAGT	TACTGAACAA	TCCGTACGTT_	J
421	TCCAGACCGC	TTTGGCCTCT	ATTAAGCTCA	TTCAGGCTTC	TGCCGTTTTG	GATTTAACCG	
481	AAGATGATTT	CGATTTTCTG	ACGAGTAACA	AAGTTTGGAT	TGCTACTGAC	CGCTCTCGTG	
541	CTCGTCGCTG	CGTTGAGGCT	TGCGTTTATG	GTACGCTGGA	CTTTGTGGGA	TACCCTCGCT	
601	TTCCTGCTCC	TGTTGAGTTT	ATTGCTGCCG	TCATTGCTTA	TTATGTTCAT	CCCGTCAACA	
661	TTCAAACGGC	CTGTCTCATC	ATGGAAGGCG	CTGAATTTAC	GGAAAACATT	ATTAATGGCG	
721	TCGAGCGTCC	GGTTAAAGCC	GCTGAATTGT	TCGCGTTTAC	CTTGCGTGTA	CGCGCAGGAA	
781	ACACTGACGT	TCTTACTGAC	GCAGAAGAAA	ACGTGCGTCA	AAAATTACGT	GCGGAAGGAG	
-				TGGCGCTCGC			
901	GCGAGGTACT	AAAGGCAAGC	GTAAAGGCGC	TCGTCTTTGG	TATGTAGGTG	GTCAACAATT	
				AGGATAAATT			
				TCTTGGCTTC			
				CGCTGGCGAC			
				TGGCCTTGCT			
	_			TTATGGTGAA			
				TGTTAACACT			
-				CAATAAAATC			
	_		_	AGCGCCGTGG			
				TCGTTATGGT			
				GACTGAGCTT			
				AGCTGCTTAT			
				TGATGTTATT			
				TGTCATGCGC			
				GTTAGGCCAG			
				TGTTCCTGAG			
				TAAAGAGATT			
				CCCTGTTTTG			
				TGGTGATTCG			
				GTATGTTTCT			
				TGGTGATTTG			
				CGTTCAGTTG			
2221	TAAATTTAAT	GTGACCGTTT	ATCGCAATCT	GCCGACCACT	CGCGATTCAA	TCATGACTTC	

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2281 GTGATAAAAG ATTGAGTGTG AGGTTATAAC GCCGAAGCGG TAAAAATTTT AATTTTTGCC
2341 GCTGAGGGGT TGACCAAGCG AAGCGCGGTA GGTTTTCTGC TTAGGAGTTT AATCATGTTT
2401 CAGACTTTTA TTTCTCGCCA TAATTCAAAC TTTTTTTCTG ATAAGCTGGT TCTCACTTCT
2461 GTTACTCCAG CTTCTTCGGC ACCTGTTTTA CAGACACCTA AAGCTACATC GTCAACGTTA
2521 TATTTTGATA GTTTGACGGT TAATGCTGGT AATGGTGGTT TTCTTCATTG CATTCAGATG
2581 GATACATCTG TCAACGCCGC TAATCAGGTT GTTTCTGTTG GTGCTGATAT TGCTTTTGAT
2641 GCCGACCCTA AATTTTTTGC CTGTTTGGTT CGCTTTGAGT CTTCTTCGGT TCCGACTACC
2701 CTCCCGACTG CCTATGATGT TTATCCTTTG AATGGTCGCC ATGATGGTGG TTATTATACC
2761 GTCAAGGACT GTGTGACTAT TGACGTCCTT CCCCGTACGC CGGGCAATAA CGTTTATGTT
2821 GGTTTCATGG TTTGGTCTAA CTTTACCGCT ACTAAATGCC GCGGATTGGT TTCGCTGAAT
2881 CAGGTTATTA AAGAGATTAT TTGTCTCCAG CCACTTAAGT GAGGTGATTT ATGTTTGGTG
2941 CTATTGCTGG CGGTATTGCT TCTGCTCTTG CTGGTGGCGC CATGTCTAAA TTGTTTGGAG
3001 GCGGTCAAAA AGCCGCCTCC GGTGGCATTC AAGGTGATGT GCTTGCTACC GATAACAATA
3061 CTGTAGGCAT GGGTGATGCT GGTATTAAAT CTGCCATTCA AGGCTCTAAT GTTCCTAACC
3121 CTGATGAGGC CGCCCCTAGT TTTGTTTCTG GTGCTATGGC TAAAGCTGGT AAAGGACTTC
3181 TTGAAGGTAC GTTGCAGGCT GGCACTTCTG CCGTTTCTGA TAAGTTGCTT GATTTGGTTG
3241 GACTTGGTGG CAAGTCTGCC GCTGATAAAG GAAAGGATAC TCGTGATTAT CTTGCTGCTG
3301 CATTTCCTGA GCTTAATGCT TGGGAGCGTG CTGGTGCTGA TGCTTCCTCT GCTGGTATGG
3361 TTGACGCCGG ATTTGAGAAT CAAAAAGAGC TTACTAAAAT GCAACTGGAC AATCAGAAAG
3421 AGATTGCCGA GATGCAAAAT GAGACTCAAA AAGAGATTGC TGGCATTCAG TCGGCGACTT
3481 CACGCCAGAA TACGAAAGAC CAGGTATATG CACAAAATGA GATGCTTGCT TATCAACAGA
3541 AGGAGTCTAC TGCTCGCGTT GCGTCTATTA TGGAAAACAC CAATCTTTCC AAGCAACAGC
3601 AGGTTTCCGA GATTATGCGC CAAATGCTTA CTCAAGCTCA AACGGCTGGT CAGTATTTTA
3661 CCAATGACCA AATCAAAGAA ATGACTCGCA AGGTTAGTGC TGAGGTTGAC TTAGTTCATC
3721 AGCAAACGCA GAATCAGCGG TATGGCTCTT CTCATATTGG CGCTACTGCA AAGGATATTT
3781 CTAATGTCGT CACTGATGCT GCTTCTGGTG TGGTTGATAT TTTTCATGGT ATTGATAAAG
3841 CTGTTGCCGA TACTTGGAAC AATTTCTGGA AAGACGGTAA AGCTGATGGT ATTGGCTCTA
3901 ATTTGTCTAG GAAATAACCG TCAGGATTGA CACCCTCCCA ATTGTATGTT TTCATGCCTC
3961 CAAATCTTGG AGGCTTTTTT ATGGTTCGTT CTTATTACCC TTCTGAATGT CACGCTGATT
4021 ATTTTGACTT TGAGCGTATC GAGGCTCTTA AACCTGCTAT TGAGGCTTGT GGCATTTCTA
4081 CTCTTTCTCA ATCCCCAATG CTTGGCTTCC ATAAGCAGAT GGATAACCGC ATCAAGCTCT
4141 TGGAAGAGAT TCTGTCTTTT CGTATGCAGG GCGTTGAGTT CGATAATGGT GATATGTATG
4201 TTGACGGCCA TAAGGCTGCT TCTGACGTTC GTGATGAGTT TGTATCTGTT ACTGAGAAGT
4261 TAATGGATGA ATTGGCACAA TGCTACAATG TGCTCCCCCA ACTTGATATT AATAACACTA
4321 TAGACCACCG CCCCGAAGGG GACGAAAAAT GGTTTTTAGA GAACGAGAAG ACGGTTACGC
4381 AGTTTTGCCG CAAGCTGGCT GCTGAACGCC CTCTTAAGGA TATTCGCGAT GAGTATAATT
4441 ACCCCAAAAA GAAAGGTATT AAGGATGAGT GTTCAAGATT GCTGGAGGCC TCCACTATGA
4501 AATCGCGTAG AGGCTTTGCT ATTCAGCGTT TGATGAATGC AATGCGACAG GCTCATGCTG
4561 ATGGTTGGTT TATCGTTTTT GACACTCTCA CGTTGGCTGA CGACCGATTA GAGGCGTTTT
4621 ATGATAATCC CAATGCTTTG CGTGACTATT TTCGTGATAT TGGTCGTATG GTTCTTGCTG
4681 CCGAGGGTCG CAAGGCTAAT GATTCACACG CCGACTGCTA TCAGTATTTT TGTGTGCCTG
4741 AGTATGGTAC AGCTAATGGC CGTCTTCATT TCCATGCGGT GCACTTTATG CGGACACTTC
4801 CTACAGGTAG CGTTGACCCT AATTTTGGTC GTCGGGTACG CAATCGCCGC CAGTTAAATA
4861 GCTTGCAAAA TACGTGGCCT TATGGTTACA GTATGCCCAT CGCAGTTCGC TACACGCAGG
4921 ACGCTTTTTC ACGTTCTGGT TGGTTGTGGC CTGTTGATGC TAAAGGTGAG CCGCTTAAAG
4981 CTACCAGTTA TATGGCTGTT GGTTTCTATG TGGCTAAATA CGTTAACAAA AAGTCAGATA
5041 TGGACCTTGC TGCTAAAGGT CTAGGAGCTA AAGAATGGAA CAACTCACTA AAAACCAAGC
5101 TGTCGCTACT TCCCAAGAAG CTGTTCAGAA TCAGAATGAG CCGCAACTTC GGGATGAAAA
5161 TGCTCACAAT GACAAATCTG TCCACGGAGT GCTTAATCCA ACTTACCAAG CTGGGTTACG
5221 ACGCGACGCC GTTCAACCAG ATATTGAAGC AGAACGCAAA AAGAGAGATG AGATTGAGGC
5281 TGGGAAAAGT TACTGTAGCC GACGTTTTGG CGGCGCAACC TGTGACGACA AATCTGCTCA
5341 AATTTATGCG CGCTTCGATA AAAATGATTG GCGTATCCAA CCTGCA
```

Analysis questions:

1) Observing the nucleotide sequence for the bacterial virus \$\psi X174\$, determine the number of bases, kilobases and megabases in this genome (each row contains 60 nucleotides grouped in 6 groups of 10 each).

1kb = 1 kilobase = 1 000 bases 1Mb = 1 megabase = 1 000 000 bases

bases	kilobases	megabases		

- 2) Determine how many bases are present in gene #1.
- 3) Observing Table #1 for the DNA length, determine what the size of this virus is (small, average, or big). Explain your answer considering the number of base pairs.

Activity #3: Getting to know the genome of bacterial virus \$\psi X174\$

Answers:

- 1) Each row has 60 nitrogenated bases, except the last one, which has 45 nitrogenated bases. There are 90 rows in total. Then, to calculate the total number of nitrogenated bases:
 - 89 rows x 60 nitrogenated bases = 5,340 nitrogenated bases
 - To the 5,340 nitrogenated bases we will add 46 nitrogenated bases in row #90. Therefore, in total we have 5,386 nitrogenated bases in this genome. This total is then placed in the table (column #1).
 - To determine the number of kilobases (kb), utilize the conversion factor, 1kb = 1 kilobase = 1000 bases. Then,

This result is then placed in the table (column #2)

• To determine the number of megabases (Mb), utilize the conversion factor, 1Mb = 1 megabase = 1 000 000 bases. Then,

This result is then placed in the table (column #3)

Column 1	Column 2	Column 3
bases	kilobases	megabases
5,386	5.386 kb	0.0053 Mb

2) Determine how many bases are present in gene #1.

IMPORTANT: In this genome, various genes can be found. The analysis will be done by referring to the gene marked as gene #1 (highlighted).

Answer: 261 nitrogenated bases

How did I come up with this result?

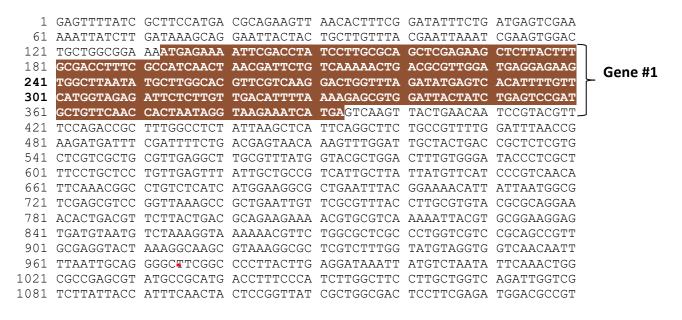
- The area of the nitrogenated bases that represent gene #1 has 5 rows.
- Remember that each row has 60 bases. Therefore, 5 rows x 60 bases equal 300 bases.
- Then, in row 1, where the gene is located, 12 bases must be subtracted (the area that is not highlighted). If we subtract 300 – 12, it equals 288 bases.
- To this result (288 bases), 27 further bases (that are not included as part of gene #1) must be subtracted from row 5. Then, 288 27 equals 261. This result represents the nitrogenated bases present in gene #1.
- 3) According to Table #1 for DNA Length used as a reference, this bacterial virus is an example of an organism with a small DNA sequence.

Referencia: Genome of the virus:

https://www.ncbi.nlm.nih.gov/nuccore/NC 001422.1?report=fasta&to=5386

>NC_001422.1 Coliphage phi-X174, complete genome

Genome for bacterial virus \$\phi\$X174



```
1141 TGGCGCTCTC CGTCTTTCTC CATTGCGTCG TGGCCTTGCT ATTGACTCTA CTGTAGACAT
1201 TTTTACTTTT TATGTCCCTC ATCGTCACGT TTATGGTGAA CAGTGGATTA AGTTCATGAA
1261 GGATGGTGTT AATGCCACTC CTCTCCCGAC TGTTAACACT ACTGGTTATA TTGACCATGC
1321 CGCTTTTCTT GGCACGATTA ACCCTGATAC CAATAAAATC CCTAAGCATT TGTTTCAGGG
1381 TTATTTGAAT ATCTATAACA ACTATTTTAA AGCGCCGTGG ATGCCTGACC GTACCGAGGC
1441 TAACCCTAAT GAGCTTAATC AAGATGATGC TCGTTATGGT TTCCGTTGCT GCCATCTCAA
1501 AAACATTTGG ACTGCTCCGC TTCCTCCTGA GACTGAGCTT TCTCGCCAAA TGACGACTTC
1561 TACCACATCT ATTGACATTA TGGGTCTGCA AGCTGCTTAT GCTAATTTGC ATACTGACCA
1621 AGAACGTGAT TACTTCATGC AGCGTTACCA TGATGTTATT TCTTCATTTG GAGGTAAAAC
1681 CTCTTATGAC GCTGACAACC GTCCTTTACT TGTCATGCGC TCTAATCTCT GGGCATCTGG
1741 CTATGATGTT GATGGAACTG ACCAAACGTC GTTAGGCCAG TTTTCTGGTC GTGTTCAACA
1801 GACCTATAAA CATTCTGTGC CGCGTTTCTT TGTTCCTGAG CATGGCACTA TGTTTACTCT
1861 TGCGCTTGTT CGTTTTCCGC CTACTGCGAC TAAAGAGATT CAGTACCTTA ACGCTAAAGG
1921 TGCTTTGACT TATACCGATA TTGCTGGCGA CCCTGTTTTG TATGGCAACT TGCCGCCGCG
1981 TGAAATTTCT ATGAAGGATG TTTTCCGTTC TGGTGATTCG TCTAAGAAGT TTAAGATTGC
2041 TGAGGGTCAG TGGTATCGTT ATGCGCCTTC GTATGTTTCT CCTGCTTATC ACCTTCTTGA
2101 AGGCTTCCCA TTCATTCAGG AACCGCCTTC TGGTGATTTG CAAGAACGCG TACTTATTCG
2161 CCACCATGAT TATGACCAGT GTTTCCAGTC CGTTCAGTTG TTGCAGTGGA ATAGTCAGGT
2221 TAAATTTAAT GTGACCGTTT ATCGCAATCT GCCGACCACT CGCGATTCAA TCATGACTTC
2281 GTGATAAAAG ATTGAGTGTG AGGTTATAAC GCCGAAGCGG TAAAAATTTT AATTTTTGCC
2341 GCTGAGGGGT TGACCAAGCG AAGCGCGGTA GGTTTTCTGC TTAGGAGTTT AATCATGTTT
2401 CAGACTTTTA TTTCTCGCCA TAATTCAAAC TTTTTTTCTG ATAAGCTGGT TCTCACTTCT
2461 GTTACTCCAG CTTCTTCGGC ACCTGTTTTA CAGACACCTA AAGCTACATC GTCAACGTTA
2521 TATTTTGATA GTTTGACGGT TAATGCTGGT AATGGTGGTT TTCTTCATTG CATTCAGATG
2581 GATACATCTG TCAACGCCGC TAATCAGGTT GTTTCTGTTG GTGCTGATAT TGCTTTTGAT
2641 GCCGACCCTA AATTTTTTGC CTGTTTGGTT CGCTTTGAGT CTTCTTCGGT TCCGACTACC
2701 CTCCCGACTG CCTATGATGT TTATCCTTTG AATGGTCGCC ATGATGGTGG TTATTATACC
2761 GTCAAGGACT GTGTGACTAT TGACGTCCTT CCCCGTACGC CGGGCAATAA CGTTTATGTT
2821 GGTTTCATGG TTTGGTCTAA CTTTACCGCT ACTAAATGCC GCGGATTGGT TTCGCTGAAT
2881 CAGGTTATTA AAGAGATTAT TTGTCTCCAG CCACTTAAGT GAGGTGATTT ATGTTTGGTG
2941 CTATTGCTGG CGGTATTGCT TCTGCTCTTG CTGGTGGCGC CATGTCTAAA TTGTTTGGAG
3001 GCGGTCAAAA AGCCGCCTCC GGTGGCATTC AAGGTGATGT GCTTGCTACC GATAACAATA
3061 CTGTAGGCAT GGGTGATGCT GGTATTAAAT CTGCCATTCA AGGCTCTAAT GTTCCTAACC
3121 CTGATGAGGC CGCCCCTAGT TTTGTTTCTG GTGCTATGGC TAAAGCTGGT AAAGGACTTC
3181 TTGAAGGTAC GTTGCAGGCT GGCACTTCTG CCGTTTCTGA TAAGTTGCTT GATTTGGTTG
3241 GACTTGGTGG CAAGTCTGCC GCTGATAAAG GAAAGGATAC TCGTGATTAT CTTGCTGCTG
3301 CATTTCCTGA GCTTAATGCT TGGGAGCGTG CTGGTGCTGA TGCTTCCTCT GCTGGTATGG
3361 TTGACGCCGG ATTTGAGAAT CAAAAAGAGC TTACTAAAAT GCAACTGGAC AATCAGAAAG
3421 AGATTGCCGA GATGCAAAAT GAGACTCAAA AAGAGATTGC TGGCATTCAG TCGGCGACTT
3481 CACGCCAGAA TACGAAAGAC CAGGTATATG CACAAAATGA GATGCTTGCT TATCAACAGA
3541 AGGAGTCTAC TGCTCGCGTT GCGTCTATTA TGGAAAACAC CAATCTTTCC AAGCAACAGC
3601 AGGTTTCCGA GATTATGCGC CAAATGCTTA CTCAAGCTCA AACGGCTGGT CAGTATTTTA
3661 CCAATGACCA AATCAAAGAA ATGACTCGCA AGGTTAGTGC TGAGGTTGAC TTAGTTCATC
3721 AGCAAACGCA GAATCAGCGG TATGGCTCTT CTCATATTGG CGCTACTGCA AAGGATATTT
3781 CTAATGTCGT CACTGATGCT GCTTCTGGTG TGGTTGATAT TTTTCATGGT ATTGATAAAG
3841 CTGTTGCCGA TACTTGGAAC AATTTCTGGA AAGACGGTAA AGCTGATGGT ATTGGCTCTA
3901 ATTTGTCTAG GAAATAACCG TCAGGATTGA CACCCTCCCA ATTGTATGTT TTCATGCCTC
3961 CAAATCTTGG AGGCTTTTTT ATGGTTCGTT CTTATTACCC TTCTGAATGT CACGCTGATT
4021 ATTTTGACTT TGAGCGTATC GAGGCTCTTA AACCTGCTAT TGAGGCTTGT GGCATTTCTA
4081 CTCTTTCTCA ATCCCCAATG CTTGGCTTCC ATAAGCAGAT GGATAACCGC ATCAAGCTCT
4141 TGGAAGAGAT TCTGTCTTTT CGTATGCAGG GCGTTGAGTT CGATAATGGT GATATGTATG
4201 TTGACGGCCA TAAGGCTGCT TCTGACGTTC GTGATGAGTT TGTATCTGTT ACTGAGAAGT
4261 TAATGGATGA ATTGGCACAA TGCTACAATG TGCTCCCCCA ACTTGATATT AATAACACTA
4321 TAGACCACCG CCCCGAAGGG GACGAAAAAT GGTTTTTAGA GAACGAGAAG ACGGTTACGC
4381 AGTTTTGCCG CAAGCTGGCT GCTGAACGCC CTCTTAAGGA TATTCGCGAT GAGTATAATT
4441 ACCCCAAAAA GAAAGGTATT AAGGATGAGT GTTCAAGATT GCTGGAGGCC TCCACTATGA
```

4501	AATCGCGTAG	AGGCTTTGCT	ATTCAGCGTT	TGATGAATGC	AATGCGACAG	GCTCATGCTG
4561	ATGGTTGGTT	TATCGTTTTT	GACACTCTCA	CGTTGGCTGA	CGACCGATTA	GAGGCGTTTT
4621	ATGATAATCC	CAATGCTTTG	CGTGACTATT	TTCGTGATAT	TGGTCGTATG	GTTCTTGCTG
4681	CCGAGGGTCG	CAAGGCTAAT	GATTCACACG	CCGACTGCTA	TCAGTATTTT	TGTGTGCCTG
4741	AGTATGGTAC	AGCTAATGGC	CGTCTTCATT	TCCATGCGGT	GCACTTTATG	CGGACACTTC
4801	CTACAGGTAG	CGTTGACCCT	AATTTTGGTC	GTCGGGTACG	CAATCGCCGC	CAGTTAAATA
4861	GCTTGCAAAA	TACGTGGCCT	TATGGTTACA	GTATGCCCAT	CGCAGTTCGC	TACACGCAGG
4921	ACGCTTTTTC	ACGTTCTGGT	TGGTTGTGGC	CTGTTGATGC	TAAAGGTGAG	CCGCTTAAAG
4981	CTACCAGTTA	TATGGCTGTT	GGTTTCTATG	TGGCTAAATA	CGTTAACAAA	AAGTCAGATA
5041	TGGACCTTGC	TGCTAAAGGT	CTAGGAGCTA	AAGAATGGAA	CAACTCACTA	AAAACCAAGC
5101	TGTCGCTACT	TCCCAAGAAG	CTGTTCAGAA	TCAGAATGAG	CCGCAACTTC	GGGATGAAAA
5161	TGCTCACAAT	GACAAATCTG	TCCACGGAGT	GCTTAATCCA	ACTTACCAAG	CTGGGTTACG
5221	ACGCGACGCC	GTTCAACCAG	ATATTGAAGC	AGAACGCAAA	AAGAGAGATG	AGATTGAGGC
5281	TGGGAAAAGT	TACTGTAGCC	GACGTTTTGG	CGGCGCAACC	TGTGACGACA	AATCTGCTCA
5341	AATTTATGCG	CGCTTCGATA	AAAATGATTG	GCGTATCCAA	CCTGCA	

Activity #4: Relating genome and phenome

BEGINNING

- 1) Using **Table #1: Genome Project**, the instructor starts the socialized discussion, generating the following questions:
 - Taking into consideration the previous activity Getting to know bacterial virus
 ^φX174, what do you think that the information on table #1 represents?

 Expected answer: the participants could say that it tells us the size of the genome or the number of nitrogenated bases (Mb) identified.
 - b. Observing column #2 in Table #1, do all organisms have the same size in their genome?
 - **Expected answer:** participants must answer that the sizes in the genome are different according to the organism.
 - c. The instructor shows **Figure #1** of this activity so that participants can make inferences and comments about what it means when we talk about the length of DNA and the number of nucleotides identified in its genome.

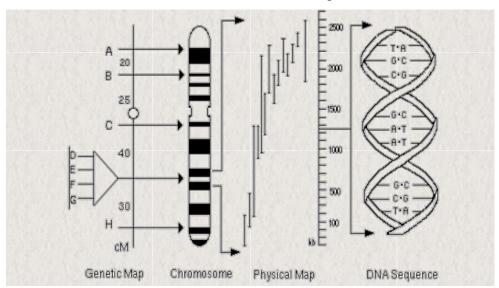


Figure #1

2) The instructor will briefly summarize what the Human Genome Project is and will show **Table #2: Genetic Cartography of the Human Being**, to observe the number of genes identified for human beings.

- 3) The instructor will use the discussion about the Human Genome Project to explore and introduce the concept of *phenome*.
 - The instructor says, "If we already know that the genome is a set of all traits
 described in an organism (for example, the sequence of nucleotides is identical
 for each species), then what are we referring to when we talk about the set of all
 physical traits in an organism?"
 - **Expected answer:** The participants could say "phoneme." Some participants may say the concept phenotype.
 - If "phenome" and "phenotype" are mentioned, the instructor will take the opportunity to explain the difference between both concepts.

Genome = it is the complete set of genetic material present in the cells of an organism. "Genome" refers to our DNA.

 Genotype = set of all coded traits in the genetic information of an organism.

Phenome = it refers to the traits that manifest in our body. The phenome would be the complete set of all phenotypical traits that manifest in an individual.

- Phenotype = set of all physical traits in a determined organism that result in the interaction of its genotype and the environment.
- 4) The instructor will hand **Worksheet #4** to the participants.

DEVELOPMENT

Part A: Relating the human genome and phenome

- The instructor will hand the participants some flashcards to sum up the difference between genome and phenome (see flashcards; these must be prepared before performing activity #4).
 - a. It will be explained to participants that **Worksheet #4** will be completed with the use of flashcards.
 - b. The instructor will hand the participants two silhouettes. In these silhouettes, participants will represent—via a writing or drawing—the information learned about the concepts of genome and phenome.

- i. It is expected that participants write or draw that the genome in the silhouettes is the same (although they could have some variations), but in the case of the phenome, it could be represented with some variation in the physical traits (some with smaller eyes, a bigger nose, the height, the kind of hair, or the presence or absence of birthmarks, among others).
- 2) In cooperative groups, participants will complete **Worksheet #4**.

Part B Relating the butterfly genome and phenome

- 1) The instructor presents **Figure #2** and asks the following question:
 - a. Do you know what species of butterfly these caterpillars belong to? Expected answer: The participants could say that they do not know to what species they belong. They could say that they are different butterflies. Some participants could say that both belong to the monarch butterfly species. If the species is not identified, the instructor will indicate that both caterpillars belong to the monarch butterfly species.
 - b. How could we relate what is observed in figure #2 with the concepts that we have studied?

Expected answer: The participants could comment that they are monarch butterfly caterpillars, but that they look different. Some may say that they have a different genotype.



Figura #2

c. What can you comment about **Figure #3** in relation to the genotype and phenotype of the monarch butterfly species?

Expected answer: All participants must indicate that figure #3 shows us that monarch butterfly caterpillars have the same genome but may have different phenotypes.



Figure #3

- 2) The instructor presents **Figure #4** to explain the expected answer, including the following explanation:
 - The species' genome is the same, but the genotype can be the same or different, because when expressing the phenotype, variations in the caterpillars' appearances were observed. There are variations that occur by different alleles = different genotypes. But there are others that depend on when, how, where and the intensity of how the proteins that code for this phenome are are expressed (for example, the colors in the butterflies' wings).



Figure #4

3) Then, the instructor will show **Figure #5** so that participants can see an example of the variations that could happen. For example, pigmentation or presence of spots in the butterfly's wings to indicate their sex.



Figure #5

CLOSURE

- 1) In socialized discussion, each group will explain the prepared silhouettes and the description related to the genome and phenome that each has.
- 2) To finish the activity, the instructor will take the opportunity to clear the doubts presented by the participants when discussing their work (discuss analysis questions).

Table #1: Genome Project

Organism	Length (Mb)	Number of genes
Fungus (yeast) Saccharomyces cerevisiae	13	6 000
Bacteria Escherichia coli (E. coli)	4.6	4 403
Insect (fruit fly) Drosophila melanogaster	150	14 000
Mammal (mouse) Mus musculus	2 500	30 000

Table #2: Genetic cartography of the Human Being

Chromosomes	Length (Mb)	Number de genes	
1	263	1873	
2	255	1113	
3	214	965	
4	203	614	
5	194	782	
6	183	1217	
7	171	995	
8	155	591	
9	145	804	
10	144	872	
11	144	1162	
12	143	894	
13	114	290	
14	109	1013	
15	106	510	
16	98	658	
17	92	, 1034	
18	85	302	
19	67	1129	
20	72	599	
21	50	386	
22	56	501	
X	164	1021	
Y	59	122	
Total: 19 447			
10tai: 19 447			

Taken from: Senior Biology, p. 277 ©BioZone

PHENOMES are the phenotypical traits that manifest in an individual. If the genome refers to our DNA, phenome refers to the traits that manifest in our body.

The phenotype, then, refers to our height, eye color, weight, blood glucose level, cholesterol, and even the concentration of proteins in our cells. Some of these traits can be indicators of illness (fever) and others surge because of a pathology (a tumor).

The phenotype changes for each person and throughout time, and it depends on many variables (our genes, our life habits, environmental factors, infections, among others).

Even two organisms with the same genotypes normally differ in their phenotypes.

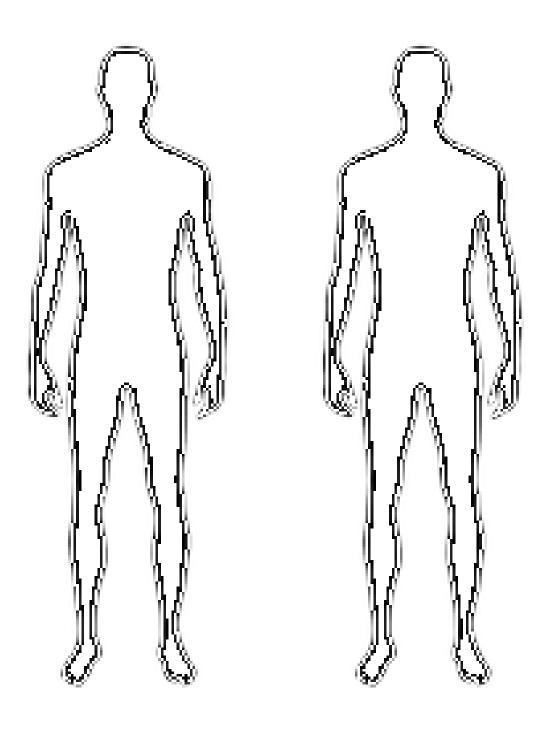
Phenotypical variation is a fundamental prior requisite for evolution via natural selection. Without phenotypical variation, there would be no evolution by natural selection.

The terms dominant and recessive phenotype describe heredity patterns of certain traits. In other words, they describe how probable it is that a determined phenotype passes on from parents to offspring.

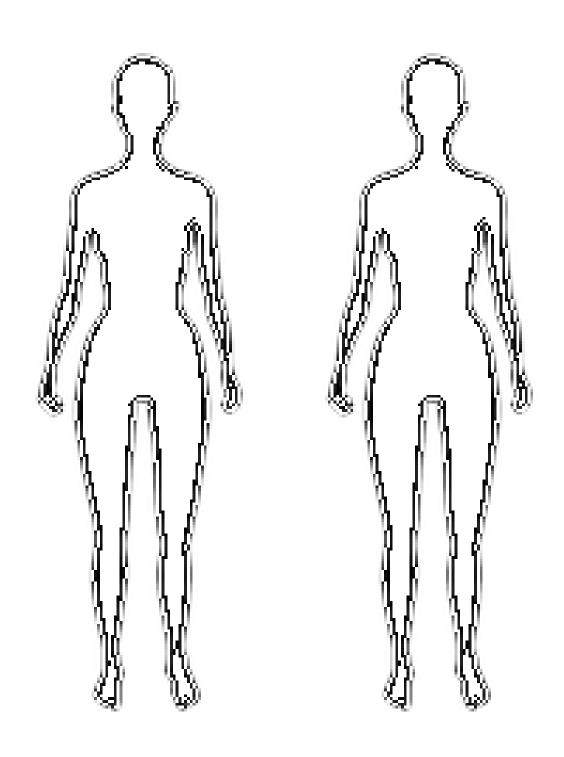
The species that reproduce sexually, like people and other animals, have two copies of each gene. Both copies, called alleles, can be slightly different between each other.

Activity #4: Relating the human genome and phenome

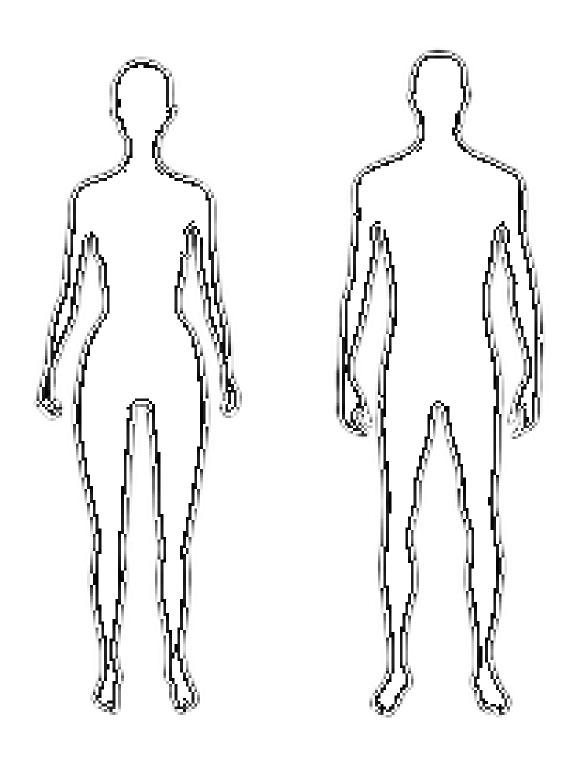
Silhouettes



Activity #4: Relating the human genome and phenome Silhouettes



Activity #4: Relating the human genome and phenome Silhouettes



Activity #4: Relating the human genome and phenome

Materials:

Flash cards
(2) silhouettes
Coloring pencils or markers

Procedure:

- 1) Using flashcards, write or draw inside the silhouettes, words or traits that would let you explain the information that you learned about the concepts: genome and phenome.
- 2) Paste the silhouettes in an area of the classroom and explain to the rest of your classmates the individuals that you created.

Analysis questions:

- 1) How did you explain or represent the concept of a genome in both silhouettes?
- 2) How did you explain or represent the concept of a phenome in both silhouettes?

Activity #4: Relating the human genome and phenome

Materials:

Flashcards
(2) silhouettes
Coloring pencils or markers

Procedure:

- 1) Using the flashcards, write or draw inside the silhouettes, words or traits that would let you explain the information that you learned about the concepts: genome and phenome.
- 2) Paste the silhouettes in an area of the classroom and explain to the rest of your classmates how the individuals that you created look.

Analysis questions:

- How did you explain or represent the concept of "genome" in both silhouettes?
 Expected answer: The participant should express in words that the genome is identical or draw identical nucleotide sequences in both figures.
- 2) How did you explain or represent the concept of "phenome" in both silhouettes?
 Expected answer: Answers may vary. They should include physical traits (depending on the phenotype selected to represent the silhouette).

Activity #5: ¿Cómo se expresan los genes?

BEGINNING

- 1) In socialized discussion, summarize the processes of replication and transcription.
 - a. The instructor will use images like **Figure #1** to summarize the process of DNA replication and transcription.

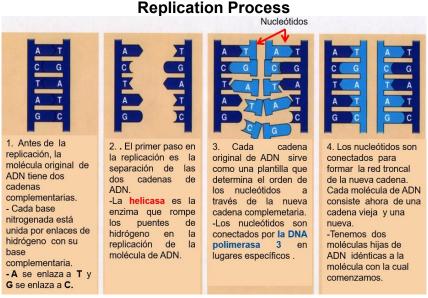


Figure #1

- 2) The instructor comments to the participants:
 - a. Do you remember Activity #1: Decipher the hidden message, where we used symbols to decipher information?
 - **Expected answer:** Participants should answer yes. Some may mention how it was done, etc.
- 3) The instructor indicates that in the next activity we will observe an example of how genetic information in some DNA nucleotides is deciphered.

DEVELOPMENT

Part A Nucleotide Sequence

- 1) The instructor will explain Worksheet #5.
 - a. Using the analogy, the instructor will compare the transcription process to a daily life situation.
 - b. The instructor comments:

Have you ever had to transcribe something? Maybe someone left you a voicemail and you had to write it down. Or maybe you took notes in class that you later carefully rewrote to help yourself review.

Then, *transcription* is a process in which information is rewritten. Transcription is something we do in our daily lives, and it is also something that our cells must do in a more specialized and tightly defined manner. In biology, **transcription** is the process in which the DNA sequence of a gene is copied in the similar alphabet of RNA.

- 2) Complete **Worksheet #5** in cooperative groups.
- 3) Once Worksheet #5 has been completed, the instructor will start a socialized discussion session with the following questions:
 - a. What relationship has what you did with the topic that we are discussing? Expected answer: It could happen that some participants may not find any similarity or that they could not distinguish the performed process. The instructor will indicate that the process that they performed is what cells must do when they express a gene.
 - b. What do you think that the underlined letters represent?

 Expected answer: The participants may say that they are nucleotides that help in the expression of the gene or may indicate that they do not know what they represent. The instructor will indicate that these nucleotide sequences represent the promoter. Promoters are located at the beginning of the gene that will be transcribed, and these (depending on the type of eukaryote or prokaryote cell) have defined nucleotide sequences, like boxes "TATA" and "TTGACA." It is the initiation of the transcription where the necessary information to activate or deactivate the regulating gene is given (this is the role of the promoter).
 - c. What do you think that bold letters represent? Expected answer: Some participants may say that these nucleotides were not necessary or were not used for gene expression. The instructor will indicate that most of the pre-mRNA in eukaryote cells contains sequences called introns, which are sequences considered trash and must be removed.
 - d. Then, what name do you think is given to the resulting nucleotide sequence?

- **Expected answer:** Participants may not know the answer. The instructor will explain that these nucleotide sequences are known as exons and that they must unite again to obtain a mature mRNA.
- e. What importance does this step of transcription have in molecular events? **Expected answer:** Participants may not know the importance. Some participants may comment that different nucleotide sequences are formed. The instructor will indicate that these processes will produce different mature mRNA and that these translate into the expression of different phenotypes.

It is important to highlight that **gene expression** is the process through which all organisms, both prokaryotic and eukaryotic, transform the information coded by the nucleic acids into the proteins necessary for their development, functioning and reproduction with other organisms.

WORKSHEET #5

Activity #5: How are genes expressed?

Materials:

Nucleotide sequence

Procedure:

- 1) Follow the instructions and identify the nucleotide sequence.
- 2) First, eliminate the letters starting with the underlined region. Write the remaining letters in box #1.
- 3) Eliminate the letters in bold. Write the remaining letters in box #2.
- 4) Regresar a la discusión socializada.

Nucleotide sequence:

GCUA*TATAAAA*AUGACUAC**GCAUC**CAG

Box #1 : Eliminate the underlined letters. W	rite the nucleotide sequence.	
Box #2: Eliminate the bold letters. Write the	e nucleotide sequence.	
	KEY	
	REI	WORKOUEET #F
Activity #5: How are genes expressed?		WORKSHEET #5
ziemi, "zi non ale genee expressed.		

Procedure:

Nucleotide sequence

Materials:

- 1) Follow the instructions and identify the nucleotide sequence.
- 2) First, eliminate the letters starting with the underlined region. Write the remaining letters in box #1.
- 3) Eliminate the letters in bold. Write the remaining letters in box #2.
- 4) Regresar a la discusión socializada.

Nucleotide sequence:

GCUATATAAAAAUGACUAC**GCAUC**CAG

Box #1: Eliminate the underlined letters. Write the nucleotide sequence.

AUGACUACGCAUCCAG

Box #2: Eliminate the bold letters. Write the nucleotide sequence.

AUGACUACCAG

Part B Check what has been learned

1) The instructor will ask the participants to observe **Illustration #1** and identify what the areas with the numbers represent by using the following concepts: promoter, mRNA, gene 1, and gene 2.

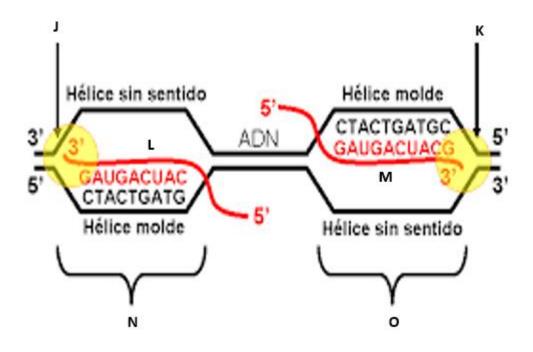


Illustration #1

- 2) The instructor leads the dynamic with the following questions:
 - a. What is shown in illustration #1?

Expected answer: Participants may say that this is a DNA process. Some may say that this is transcription.

- b. What letter or letters represent the promoter?
 - **Expected answer:** Participants may say that the promoter is represented by letters J and K. This is the correct answer.
- c. Explain where the mRNA is represented.

as an example that this occurs in all genes.

- **Expected answer:** Letters L and M represent mRNA. The instructor must highlight that this process is occurring simultaneously in various sections of a long chain of nucleotides that form the DNA (in any of the DNA strands).
- d. In what part of the illustration does gene expression occur?
 Expected answer: Letters N and O represent two different genes. This serves

3) To sum up, the instructor will show **Illustration #2 Steps of Transcription**, to highlight that gene expression occurs in the initiation step, where the promoter activates or deactivates the gene. In other words, although a species has the same genotype, it is in this step where genes express the different traits or not, the phenotype. This explains that a species have the same genotype and different phenotypes. Remember that different environmental conditions also influence this expression.

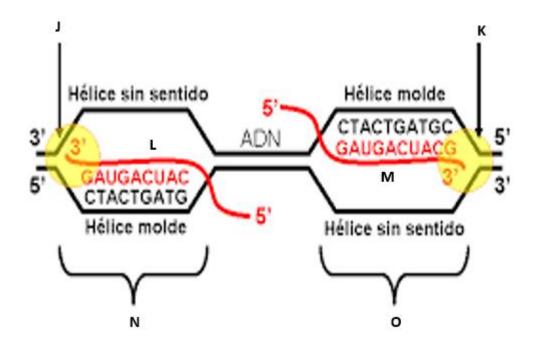
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Illustration #2: Steps of Transcription

KEY

promoter promoter

mRNA



CLOSURE

- 1) In cooperative groups, participants will answer the following question: How does gene expression connect to an organism's phenotype?
 - **Expected answer:** Genes that are expressed are the ones that will be seen in the phenotype.
 - Participants may present their answers by using a drawing, writing a paragraph, roleplaying it, by writing a song, a concrete poem, or any kind of artistic expression.
- 2) The participants will share their answers with the rest of the group.

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