The four chemical bases in DNA (A, C, G, and T) create a code. Cells “read” this DNA code to make proteins, the building blocks of all organisms.

**This is done in two steps:**

1. Copying the directions – **Transcription**

2. Reading the copy to string together the small molecules (amino acids) that make up a protein – **Translation**.

**1. Making a Copy of DNA – Transcription**

Cells read DNA in small portions (genes) to create

a protein. To do this, the cell must first make a copy of the gene’s code to send to the protein-building machinery (the ribosome and transfer RNA, or tRNA). This process is called transcription. Using the following materials, follow the steps below to see how this is done.

***You will need:***

**Your licorice and marshmallow model of DNA**

**9 green marshmallows**

**9 yellow marshmallows**

**9 orange marshmallows**

**9 pink marshmallows labeled “U”**

**6 toothpicks broken or cut in half (12 half-toothpicks total)**

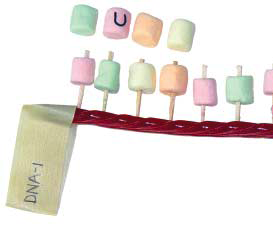
**1 piece black licorice**

**Step 1: Unzip your DNA.** Cells copy only one side of the DNA ladder.

In order to make this copy, the chemical bases forming the rungs of the DNA ladder must be separated.

• Cut or break in the middle the toothpicks in your model to separate the chemical bases and unzip the DNA ladder.

• Set the unlabeled backbone (with chemical bases attached) aside.

**Step 2: Begin to form your mRNA strand.**

The exposed chemical bases, or nucleotides of the unzipped DNA are used to make the copy. This copy is called messenger RNA (mRNA). The mRNA molecule is also made of a backbone and the same chemical bases as DNA. There is one exception however – instead of Thymine (T), mRNA uses Uracil (U).



The chemical bases in mRNA form pairs in the same way as DNA:

Adenine (A) binds with Uracil (U)

Guanine (G) binds with Cytosine (C).

• Place your backbone labeled “DNA-1” or “DNA-2” (depending on which you used to make your model) in front of you.

• Follow the rules of base pairing to make your mRNA copy of the DNA code by lining up colored marshmallows with their appropriate match.

**Step 3: The chemical bases of mRNA are also attached to a backbone as in DNA.**

• Attach the new chemical bases to a piece of black licorice backbone using toothpicks cut or broken in half. This forms a new mRNA copy of your DNA strand.



• Label this new strand mRNA-1 or mRNA-2 (the same number as your DNA strand) on the left end of the backbone.

**2. Reading a Copy of the DNA Instructions to Assemble a Protein – Translation**

The mRNA copy of DNA is essentially a recipe for assembling a protein. Proteins are built from small molecules called amino acids. When the mRNA copy travels from the nucleus to the cytoplasm, it is read and the appropriate amino acids are assembled with the help of a ribosome and tRNA. **This process is called translation.**

**Using the following list of materials, follow the steps below to see how this is done.**

***You will need:***

**Your new mRNA strand**

**1 large oval cut-out (ribosome)**

**Two of each colored circle cut-out (amino acids)**

**4 crescent-shaped cut-outs (tRNA)**

**Tape**

**Step 1: Begin to create your protein.**

In order for mRNA to be read, it must travel from the nucleus to the cytoplasm and attach to a ribosome. Place your large oval cutout behind the mRNA sequence to simulate the ribosome’s role in translation.

• mRNA is read in groups of three chemical bases, or nucleotides. Each group of three tells the cell which amino acid to assemble. In other words, each group of three is a “code” for a particular amino acid.

**Look at the first 3 chemical bases on the left end of your mRNA strand.**

• Bring a crescent-shaped cut-out (tRNA) to the first three and write the anti-codon that this tRNA must have in order to attach to these three nucleotides. (Ex. If your first three nucleotides are AUG, write UAC on the cresent.

• Now find the amino acid, based on the mRNA sequence that the tRNA will bring with it. Use the Amino Acid Key below to determine which amino acid these 3 chemical bases code for. Because we are doing a short protein sequence, the chart only shows 7 of the possible 22 amino acids. At the end of this worksheet there is a listing of all the amino acids so you are familiar with them. Note that the start codon codes for an amino acid (Met), but the stop codon does not code for an amino acid. When the stop codon is reached the ribosome falls off the mRNA and translation stops.

• Place the colored, circle cut-out representing that amino acid on the

table into the crescent shape of the tRNA. In reality in our cells, each tRNA attaches to a specific amino acid before it goes to the mRNA strand and then brings the correct amino acid to the mRNA. This perfect relationship exists because the mRNA’s codon (three nucleotides together, match a tRNA’s anticodon (opposite of the mRNA code).

**AMINO ACID KEY**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Code | AAA | ACC | ACU | AUG | CAU | UAA | UCU | UUG |
| Amino Acid | Lys  Yellow | Thr  Pink | Thr  Pink | Met (start) green | His  Purple | Stop (translation ends) | Ser  Gray | Trp  blue |

**Step 2: Continue to create the protein.**

• Repeat Step 1 for each group (or code) of three nucleotides on the mRNA strand, making sure to tape the amino acids together as you go. This is how it is done in our cells. As each amino acid is brought to the mRNA sequence, it attaches to the amino acid next to it, forming the protein. After the amino acids have joined, the tRNA leaves and the ribosome moves down the sequence to the next three nucleotides, or codons.

**When you have all of the appropriate amino acids lined up and taped together, you have a protein!**

**Record your results here:**

1) What was your initial DNA sequence?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2) What was your mRNA sequence?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

3) What were the amino acids that made up your protein sequence? (Ex. Met, Lys, Thr, etc.)

You do not need to include the stop codon because it does not code for an amino acid.

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The Genetic Code:

How Nucleotides Translate into Amino Acids, which Make Proteins

|------------------Second Base of Codon ------------------|

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| First Base of Codon  🡻 | U | C | A | G | Third Base of Codon  🡻 |
| U | UUU = Phe  UUC = Phe  UUA = Lue  UUG = Lue | UCU = Ser  UCC = Ser  UCA = Ser  UCG = Ser | UAU = Tyr  UAC = Tyr  UAA = stop  UAG = stop | UGU = Cys  UGC = Cys  UGA = stop  UGG = Trp W | U |
| C |
| A |
| G |
| C | CUU = Lue  CUC = Lue  CUA = Lue  CUG = Lue | CCU = Pro  CCC = Pro  CCA = Pro  CCG = Pro | CAU = His  CAC = His  CAA = Gln  CAG = Gln | CGU = Arg  CGC = Arg  CGA = Arg  CGG = Arg | U |
| C |
| A |
| G |
| A | AUU = Ile  AUC = Ile  AUA = Ile  AUG = Met (start) | ACU = Thr  ACC = Thr  ACA = Thr  ACG = Thr | AAU = Asn  AAC = Asn  AAA = Lys  AAG = Lys | AGU = Ser  AGC = Ser  AGA = Arg  AGG = Arg | U |
| C |
| A |
| G |
| G | GUU = Val  GUC = Val  GUA = Val  GUG = Val | GCU = Ala  GCC = Ala  GCA = Ala  GCG = Ala | GAU = Asp  GAC = Asp  GAA = Glu  GAG = Glu | GGU = Gly  GGC = Gly  GGA = Gly  GGG = Gly | U |
| C |
| A |
| G |

**\* Interesting Fact about the Genetic Code: It is IDENTICAL for all living things!!!**

**What does that tell you about its evolutionary history?**