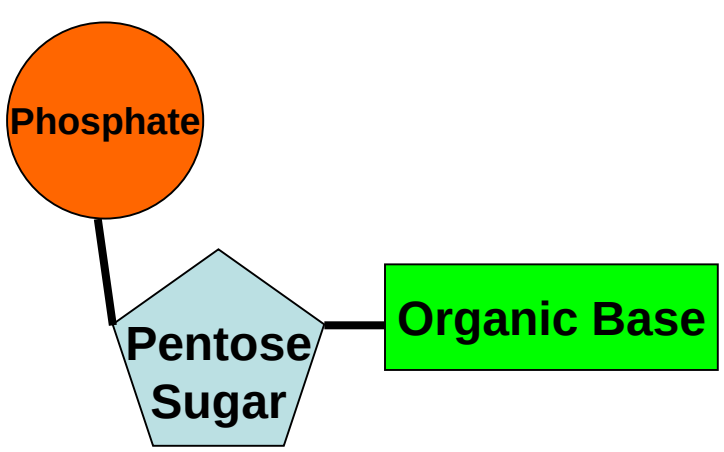
Nucleic Acids

What are Nucleic Acids?

- Write down some key ideas.
  - Be prepared to share them with the group.

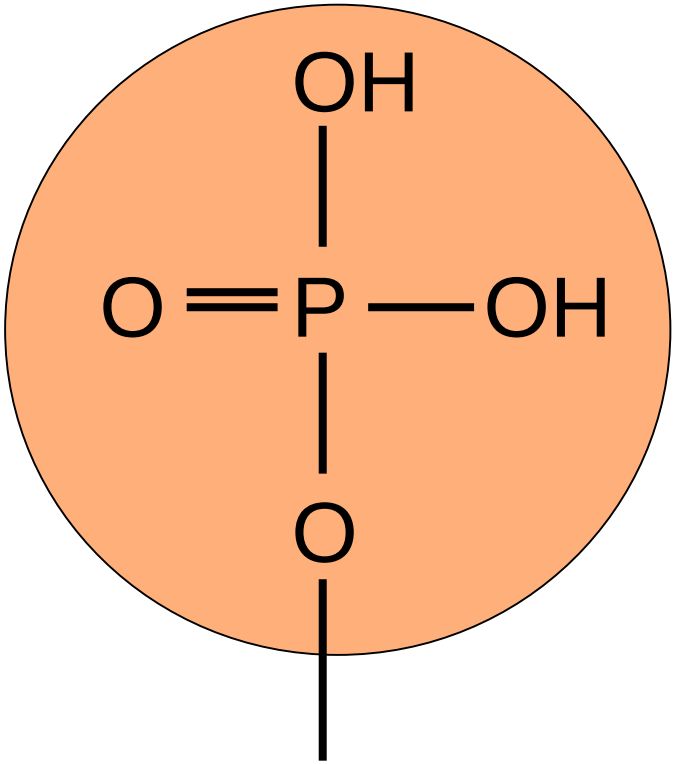
Nucleotides

- Made up of 3 components:
  - A Phosphate Group
  - A Pentose Sugar
  - An Organic Base



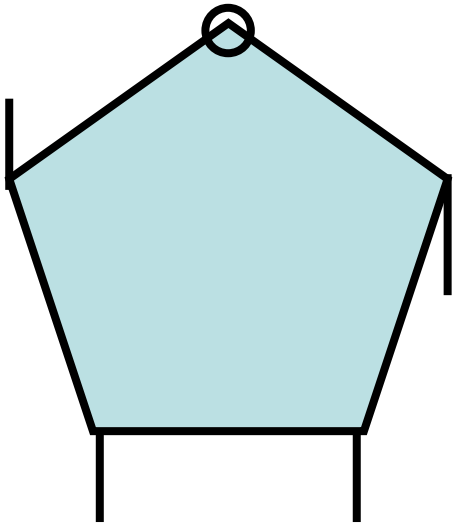
This is the structure of one nucleotide.

Phosphate Group

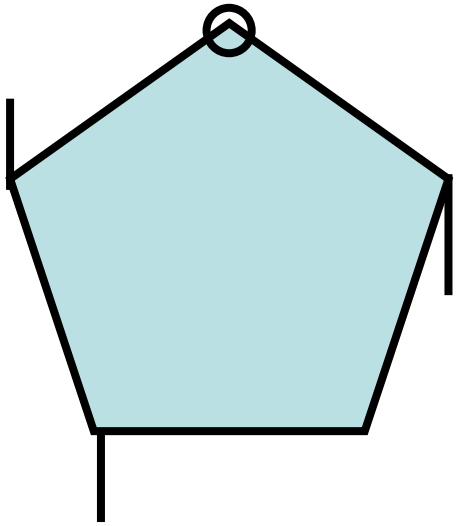


You don’t need to know this.

Pentose Sugar



Ribose



Deoxyribose

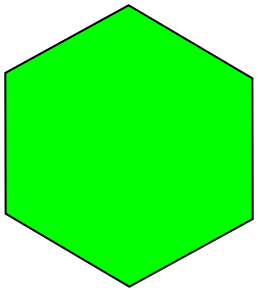
Organic Bases

- There are two groups:

Pyrimidines:

Made of a single six-sided ring.

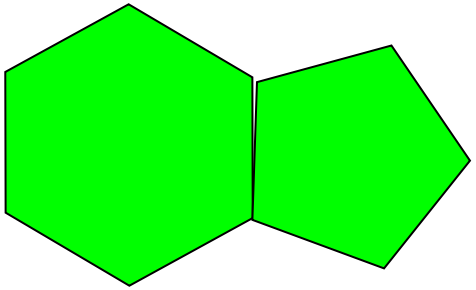
(longer name, smaller molecule)



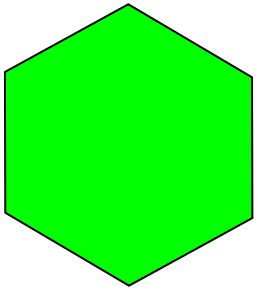
Purines:

A six-sided ring joined to a five-sided ring

(shorter name, larger molecule)

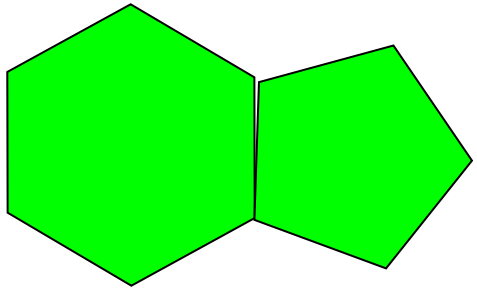


Pyrimidines



- One-ring structure.
- Include:
  - Cytosine
  - Thymine
  - Uracil

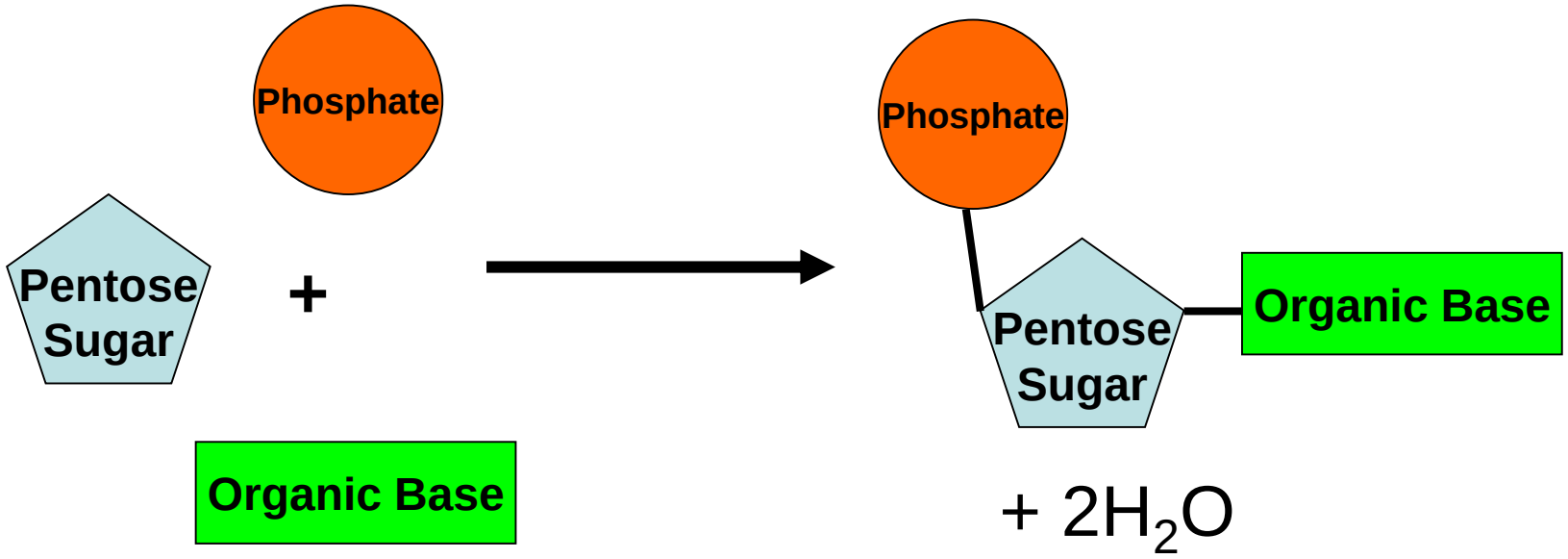
Purines



- Two-ring structure.
- Include:
  - Adenine
  - Guanine

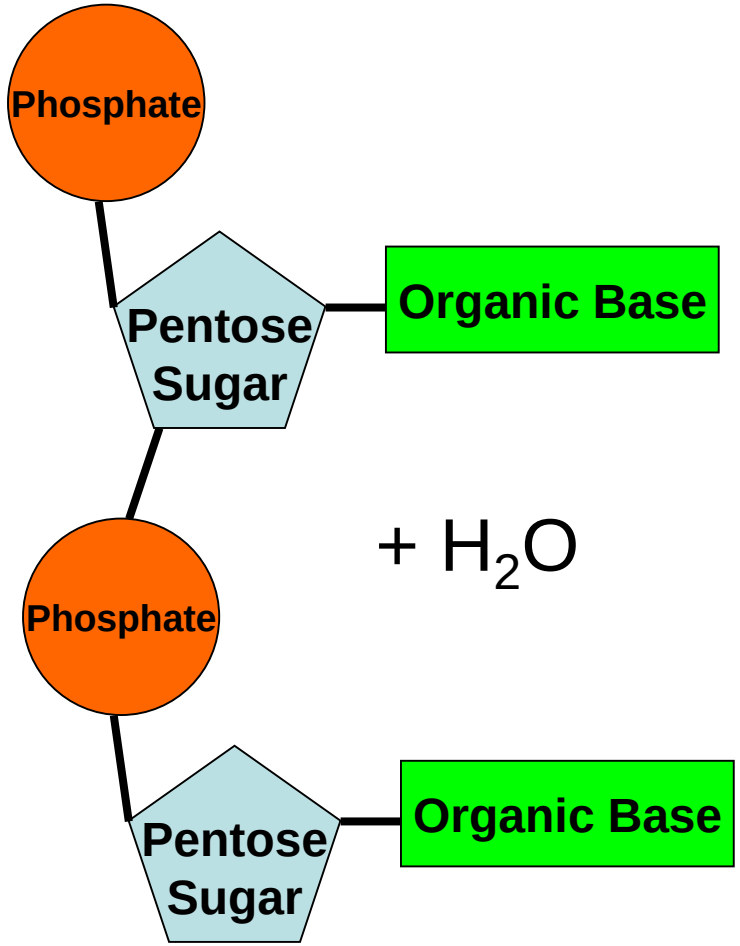
Formation of a Nucleotide

- The phosphate, pentose sugar and organic base are joined together as a result of a Condensation Reaction.



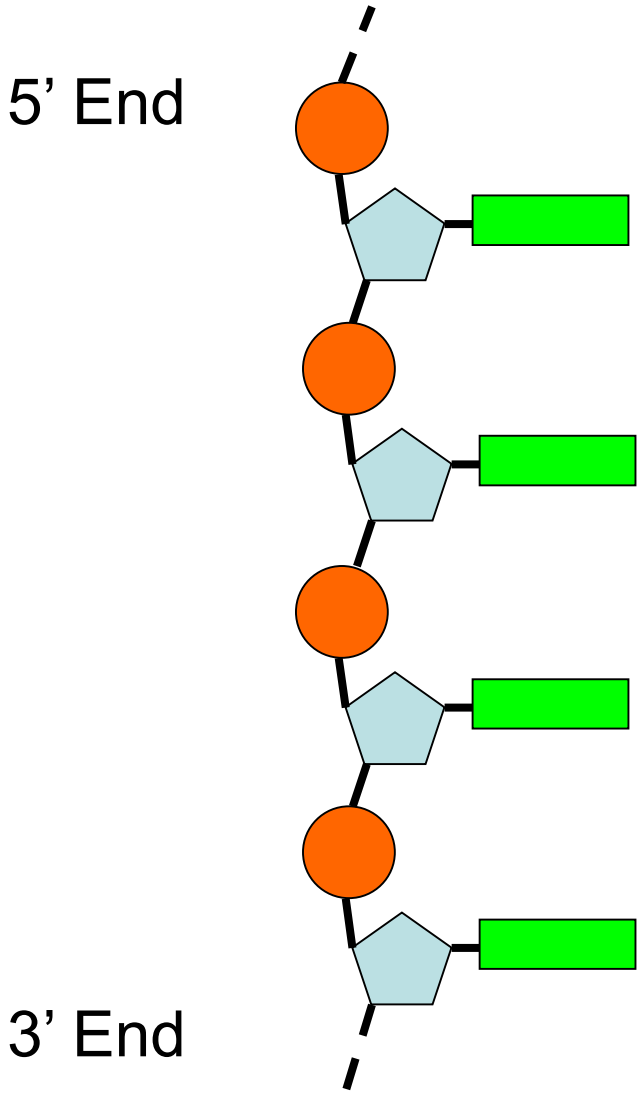
Formation of a Dinucleotide

- The single nucleotide monomers are also joined together as a result of a Condensation Reaction.



Formation of a Polynucleotide

- Continued linking of mononucleotides in this way form a polynucleotide.
  - Such as RNA.



RNA

- Ribonucleic Acid.
- Pentose sugar is always Ribose.
- Consists of a single strand of joined nucleotides.
- Organic bases are:
  - Adenine, Guanine, Cytosine & Uracil.

Purines

Pyrimidines

RNA

- Three types of RNA:
  - Ribosomal RNA (rRNA)
  - Transfer RNA (tRNA)
  - Messenger RNA (mRNA)

  - All important for protein synthesis.

Ribosomal RNA

- Large molecule.
- Major constituent of ribosomes.
- Base sequence is similar in all organisms.

- Review ribosomes as cell organelles.

Transfer RNA

- Small molecule (approx. 80 nucleotides)
- At least 20 types of tRNA that can each carry an amino acid.
- Single stranded chain folded into a clover leaf shape.

Messenger RNA

- Large, straight, single chain molecule (1000s nucleotides).
- Manufactured in the nucleus but then leaves via nuclear pores into cytoplasm.
- Acts as a temporary copy of DNA for use in protein synthesis.

DNA

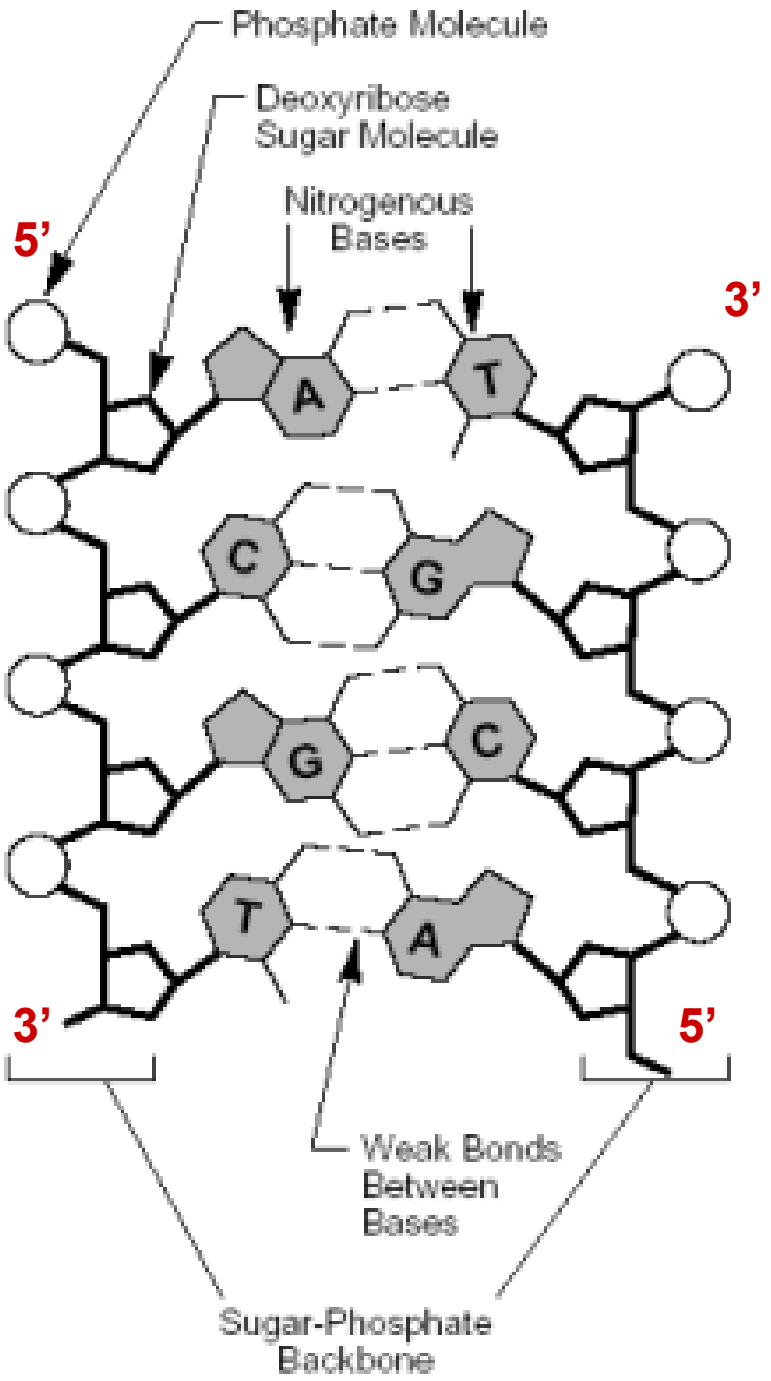
- Deoxyribonucleic Acid.
- Pentose sugar is always Deoxyribose.
- Consists of a double strand of joined nucleotides.
- Strands are joined by Hydrogen bonds.
- Organic bases are:
  - Adenine, Guanine, Cytosine & Thymine.

Purines

Pyrimidines

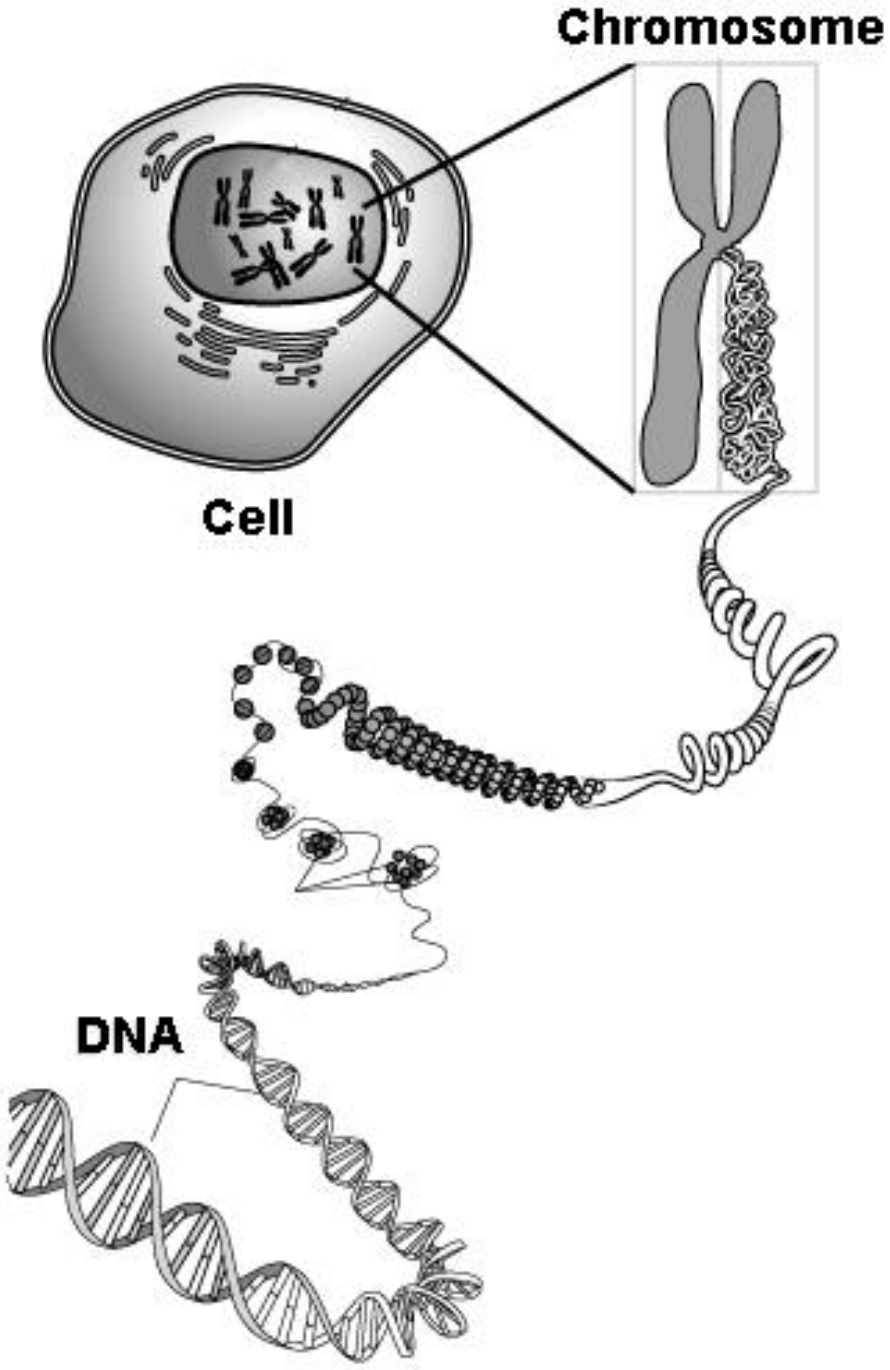
DNA Structure

- Discovered in 1953 by James Watson & Francis Crick.
- Sugar-phosphate backbones are Antiparallel.
- Rungs are all equal length.



DNA Structure

- 10 Base pairs per turn.
- 6 billion base pairs in total mammalian genome.
- Almost infinite number of possible base sequences.



Homework

- Write notes (to be handed in & marked) on DNA replication.
  - Use diagrams.
  - Include all of the following keywords:

Semi - conservative	Meselsohn & Stahl
Template	Nitrogen 15
Helicase	Replication fork
Complementary	Topoisomerase
Polymerase	Nucleotides
DNA Ligase	Proofreading

Then answer the DNA Replication exam question, again to be handed in and marked.

DNA Replication

- Hydrogen bonds between bases are broken by Helicase.
- The two strands separate.
- Each exposed strand acts as a template for a new strand to be made.
- Complementary nucleotides bind to the exposed nucleotides.
- DNA Polymerase joins all the new nucleotides together.

Complications

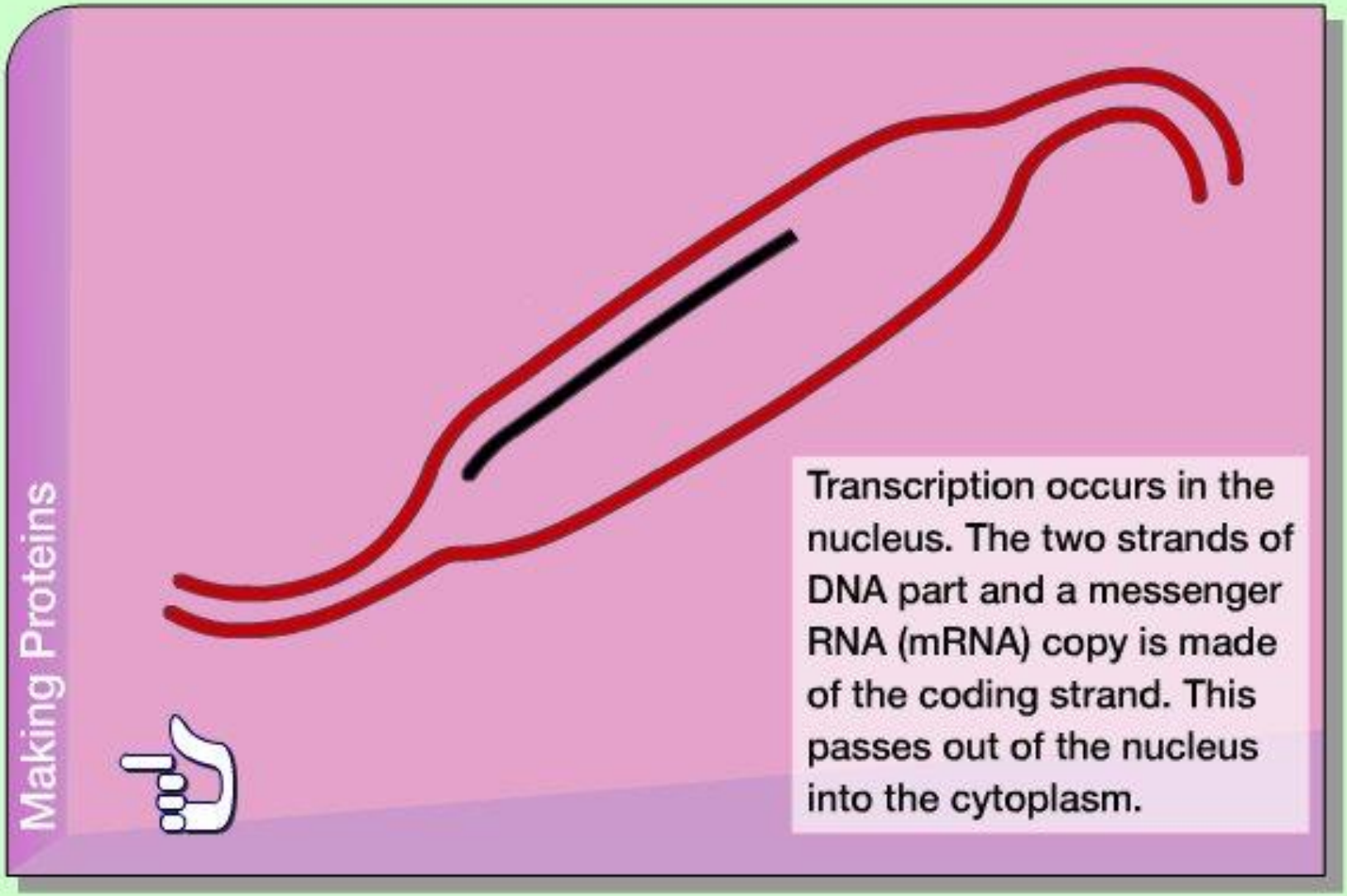
- In practice the process is more complex.
  - Topoisomerase cuts one of the strands beforehand, allowing it to untwist during replication.
  - DNA splits a number of times along its length.
  - Each replication fork is worked on simultaneously – speeds up the process.
  - DNA Ligase then joins all the pieces together.
  - One strand built up as one long strand, the other is built in short pieces which are later joined together by DNA Ligase.
  - Proofreading Endonuclease cuts off any bases incorrectly paired.

Semi Conservative Replication - The Evidence

- Three possible methods.
  - Conservative, Semi Conservative or Dispersive.
- Meselson & Stahl experiments rule out Conservative and Dispersive, but are consistent with Semi Conservative.

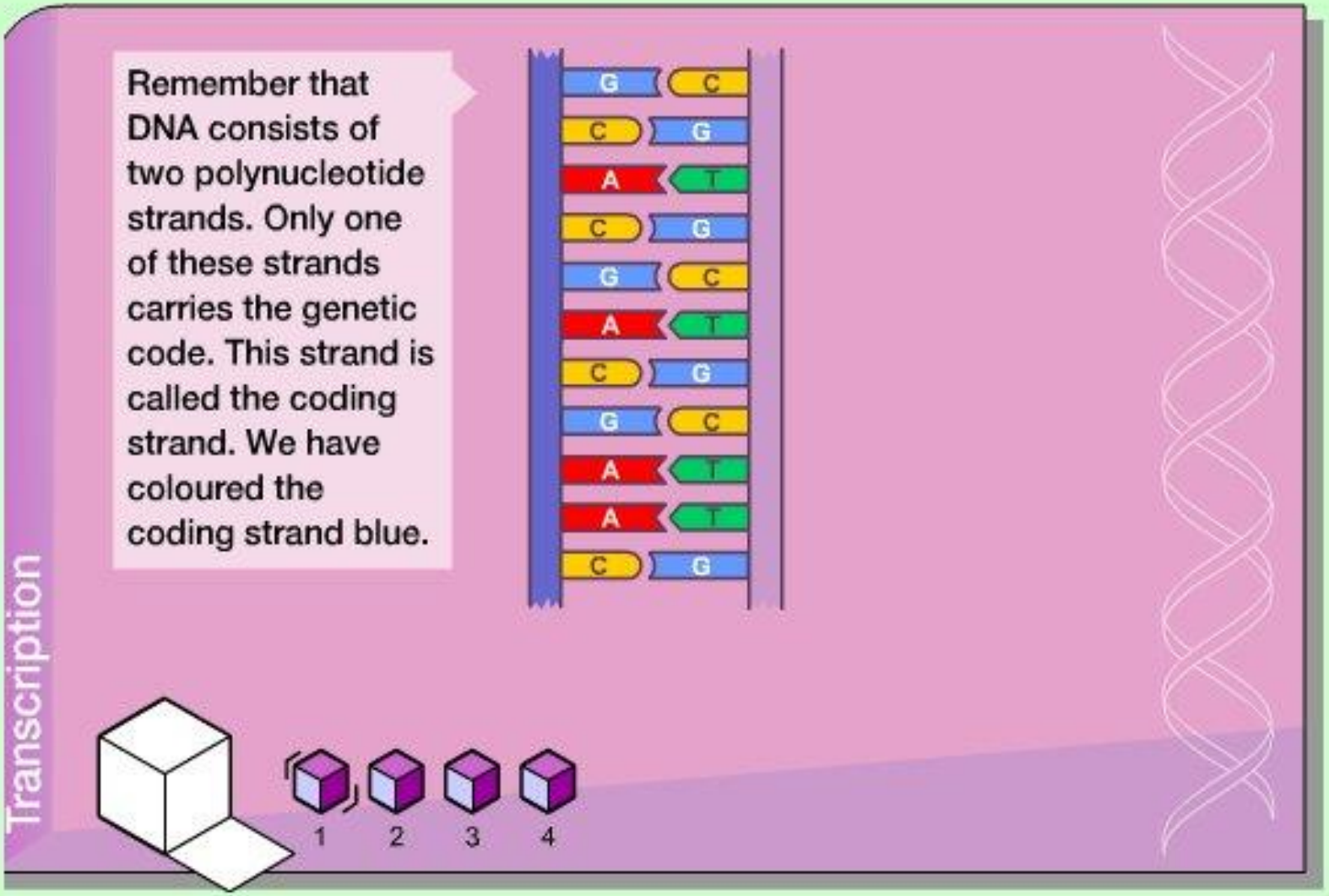
Making Proteins

Protein synthesis involves two main steps - transcription and translation. Look at the animation below. It shows the parts of the cell which are involved in making proteins.



Transcription

You've just seen how a cell makes proteins. Now let's look at the first step in protein synthesis, transcription, in more detail. It involves making an mRNA copy of the genetic code. Have a look at the animation to see how this is done.



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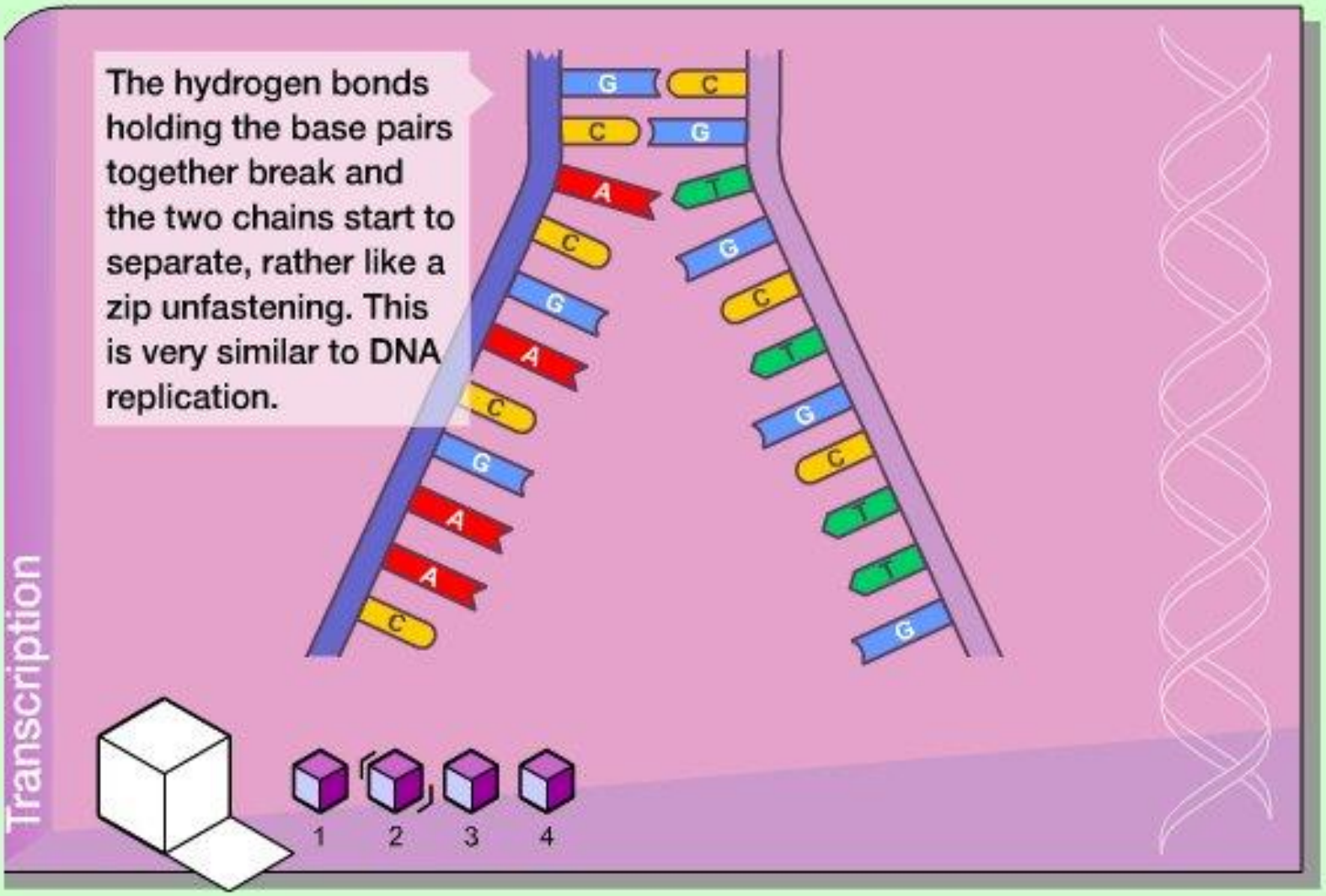

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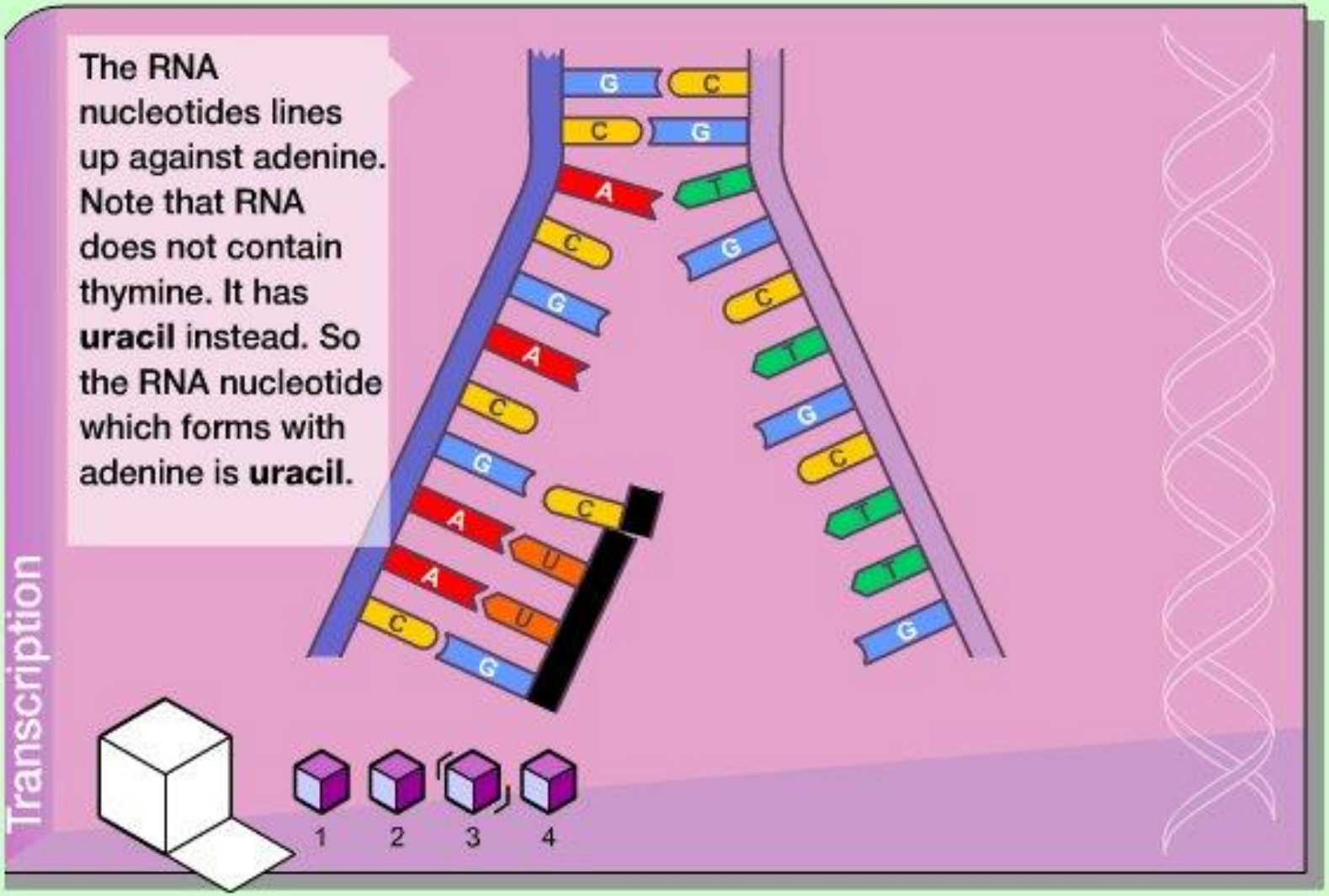

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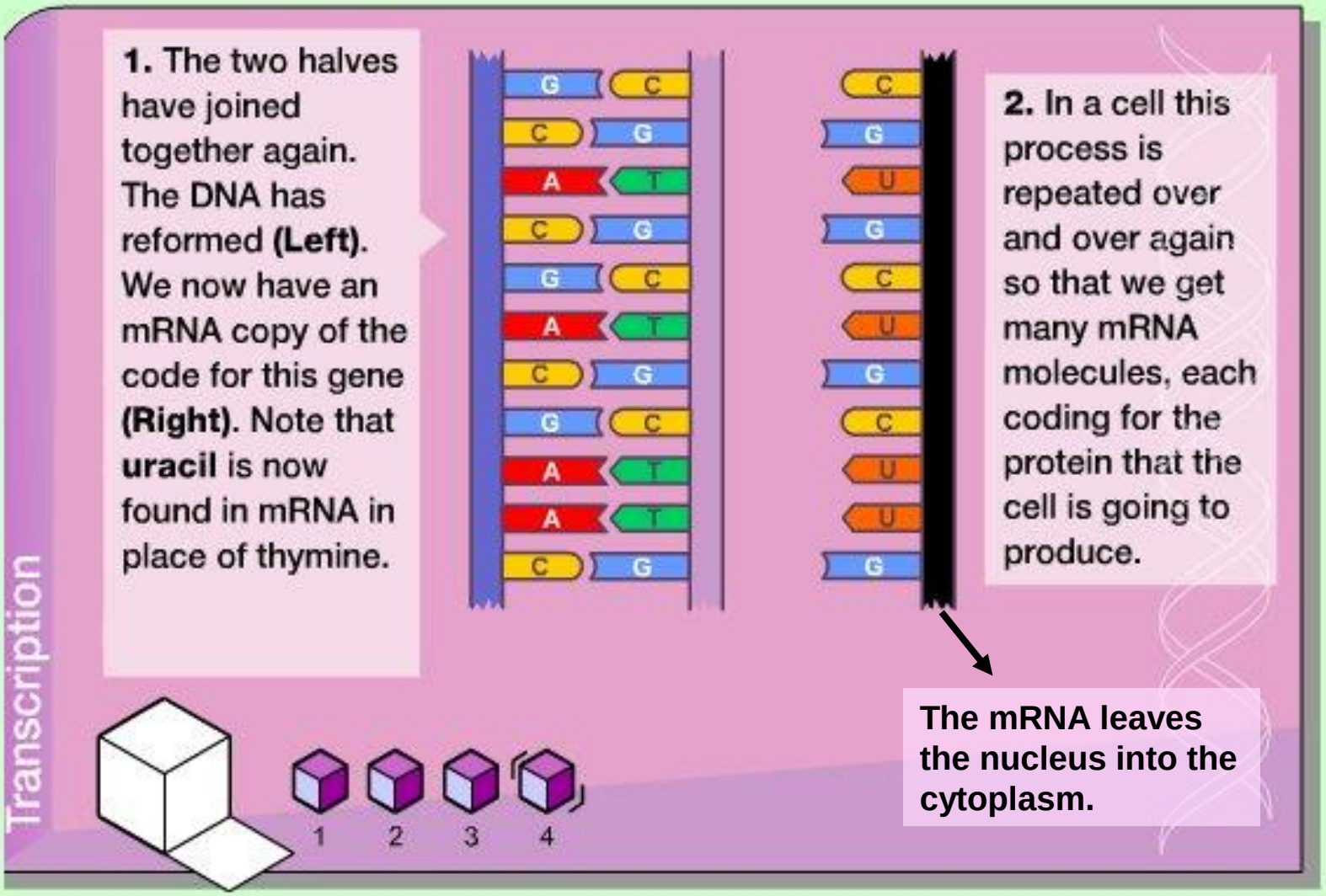
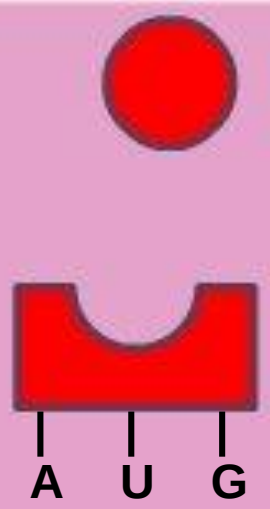
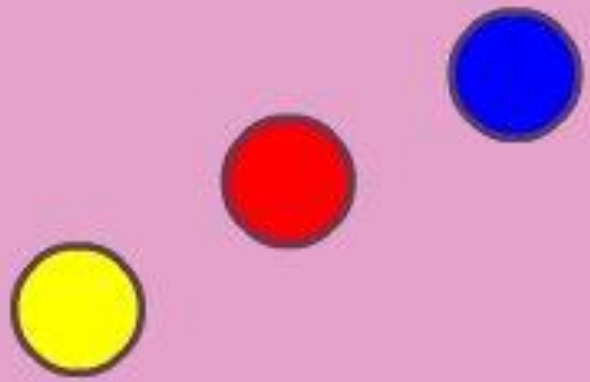


Meanwhile…

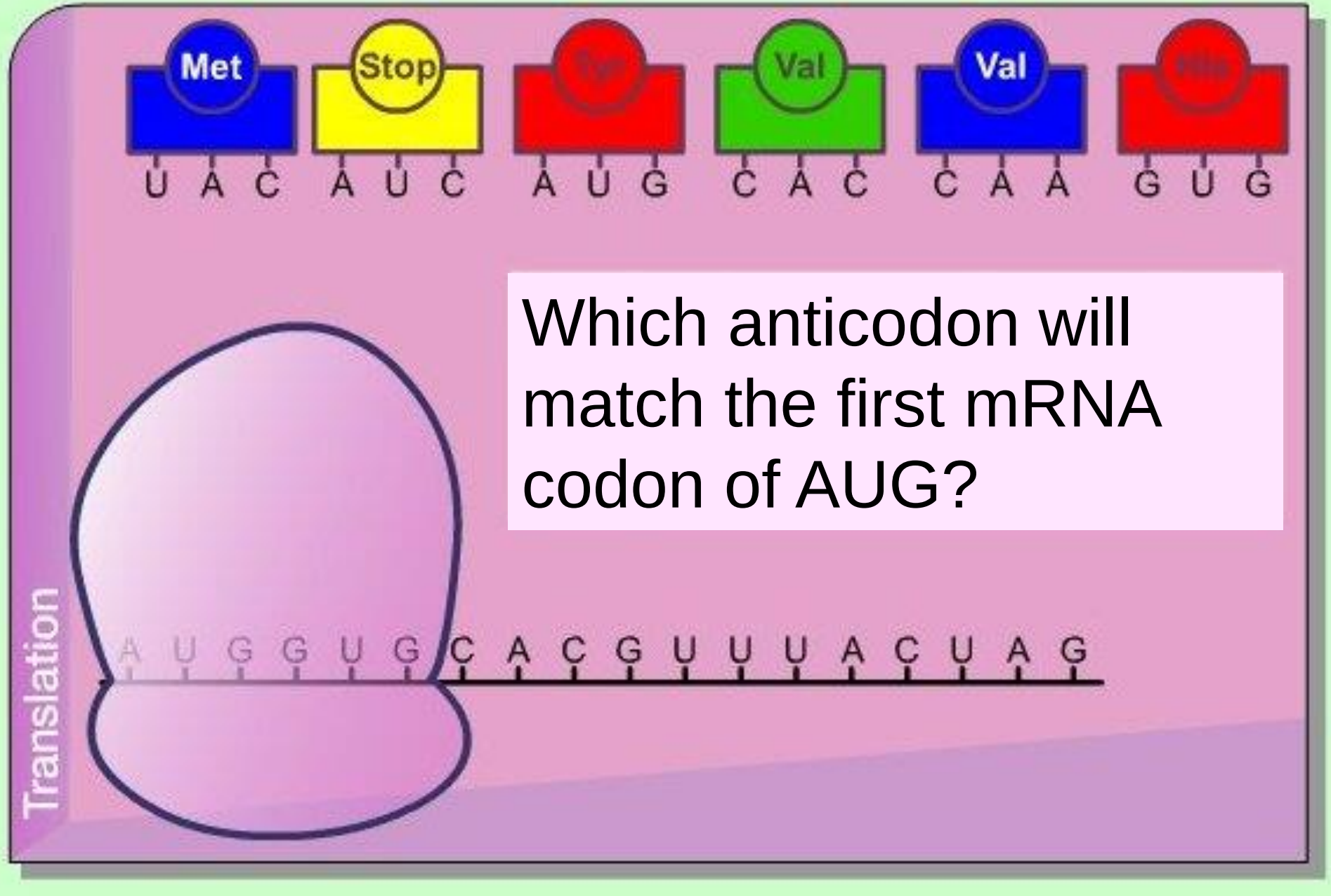
Amino acid molecules are found in the cytoplasm of the cell. An amino acid is picked up by a molecule of transfer RNA (tRNA).



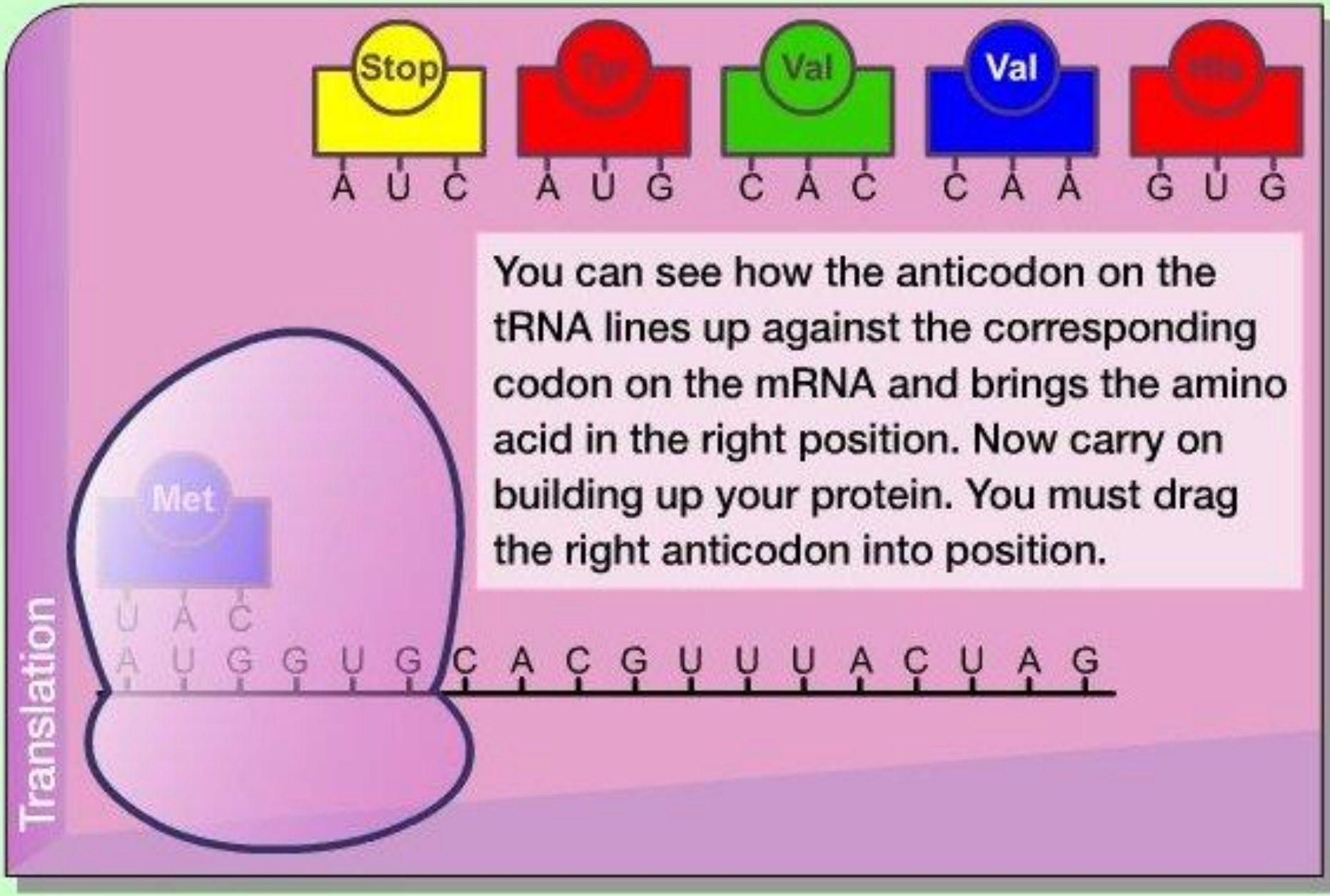


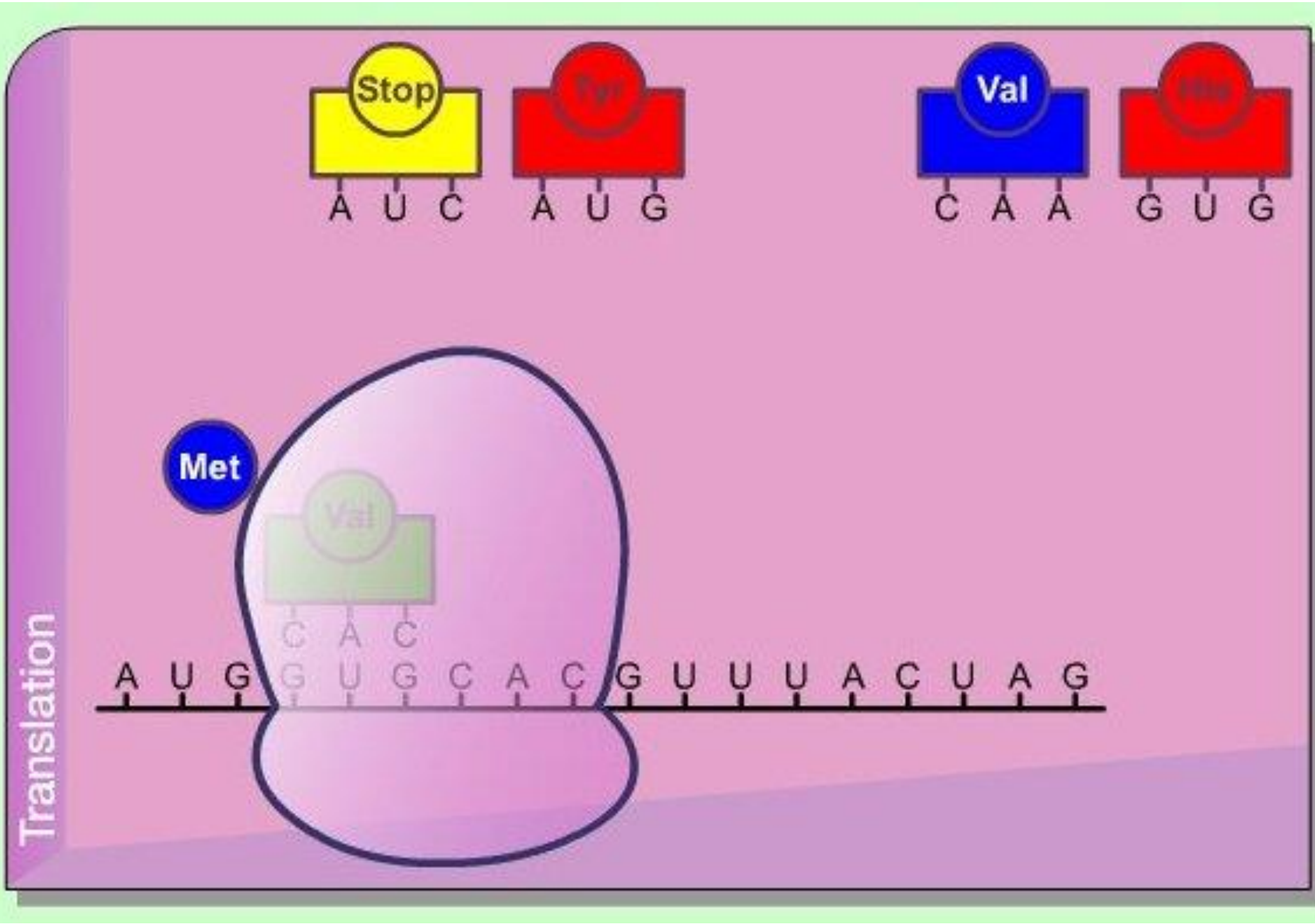
Different types of tRNA pick up different amino acids. The tRNA and its amino acid go to the ribosomes.

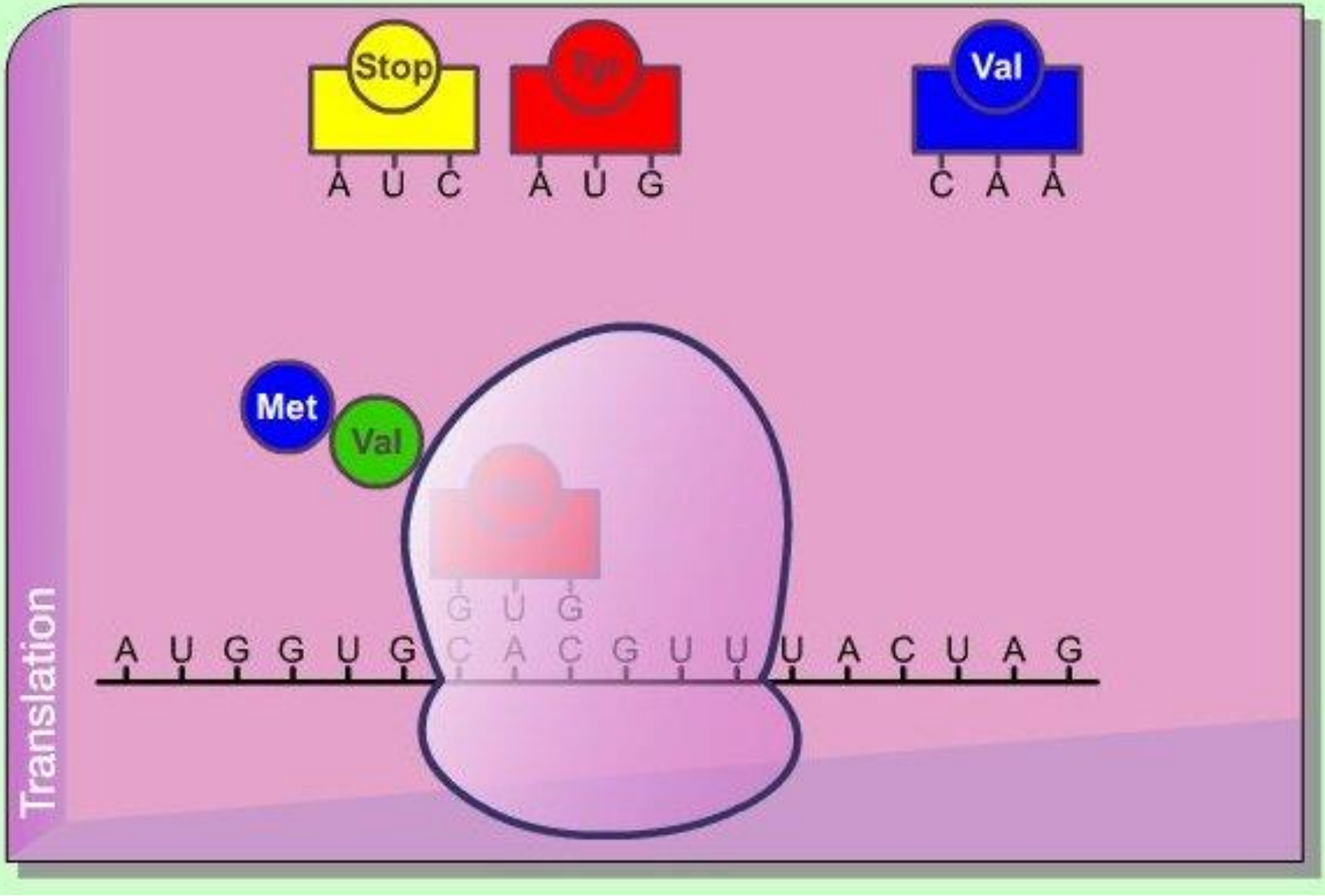
Making Proteins

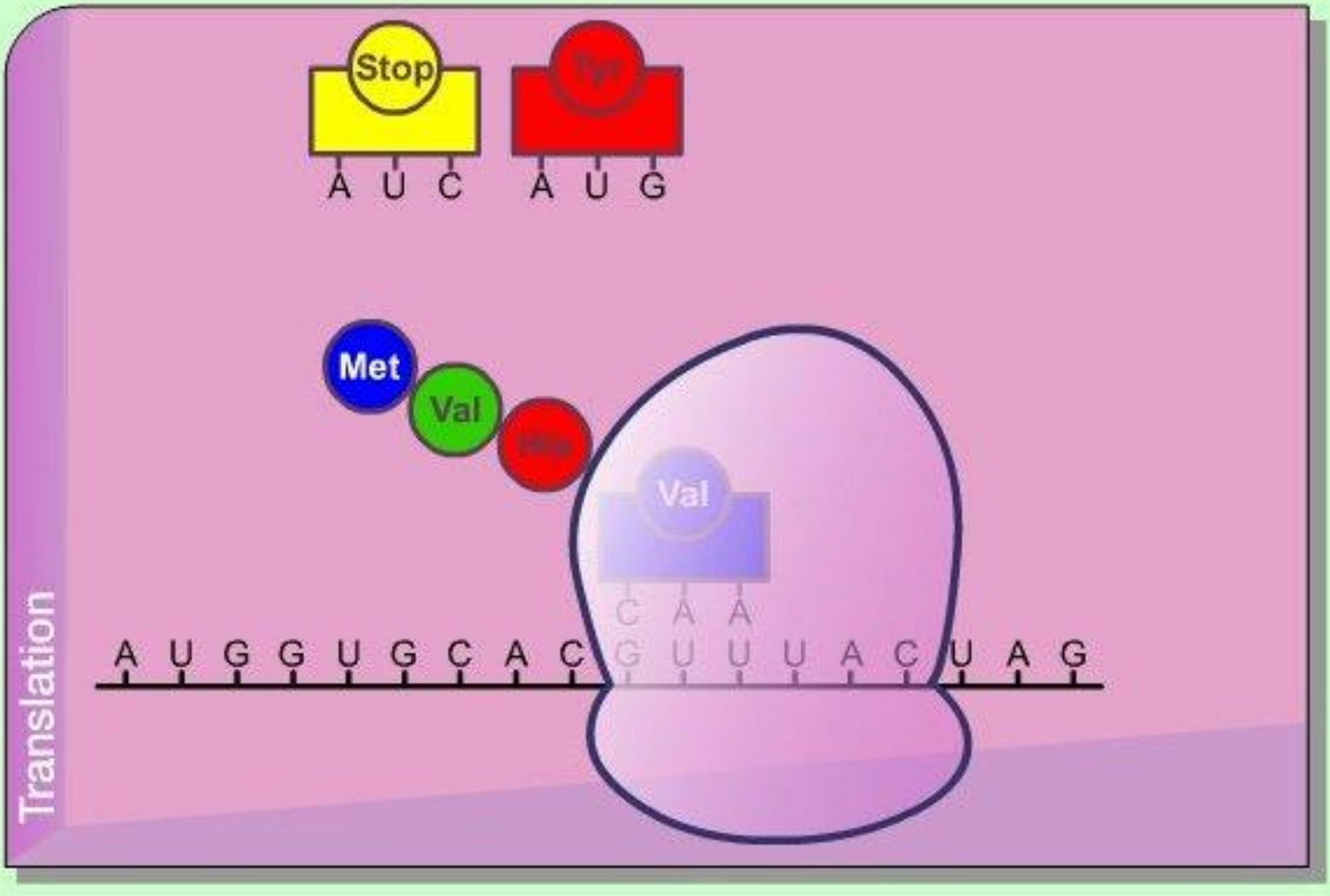


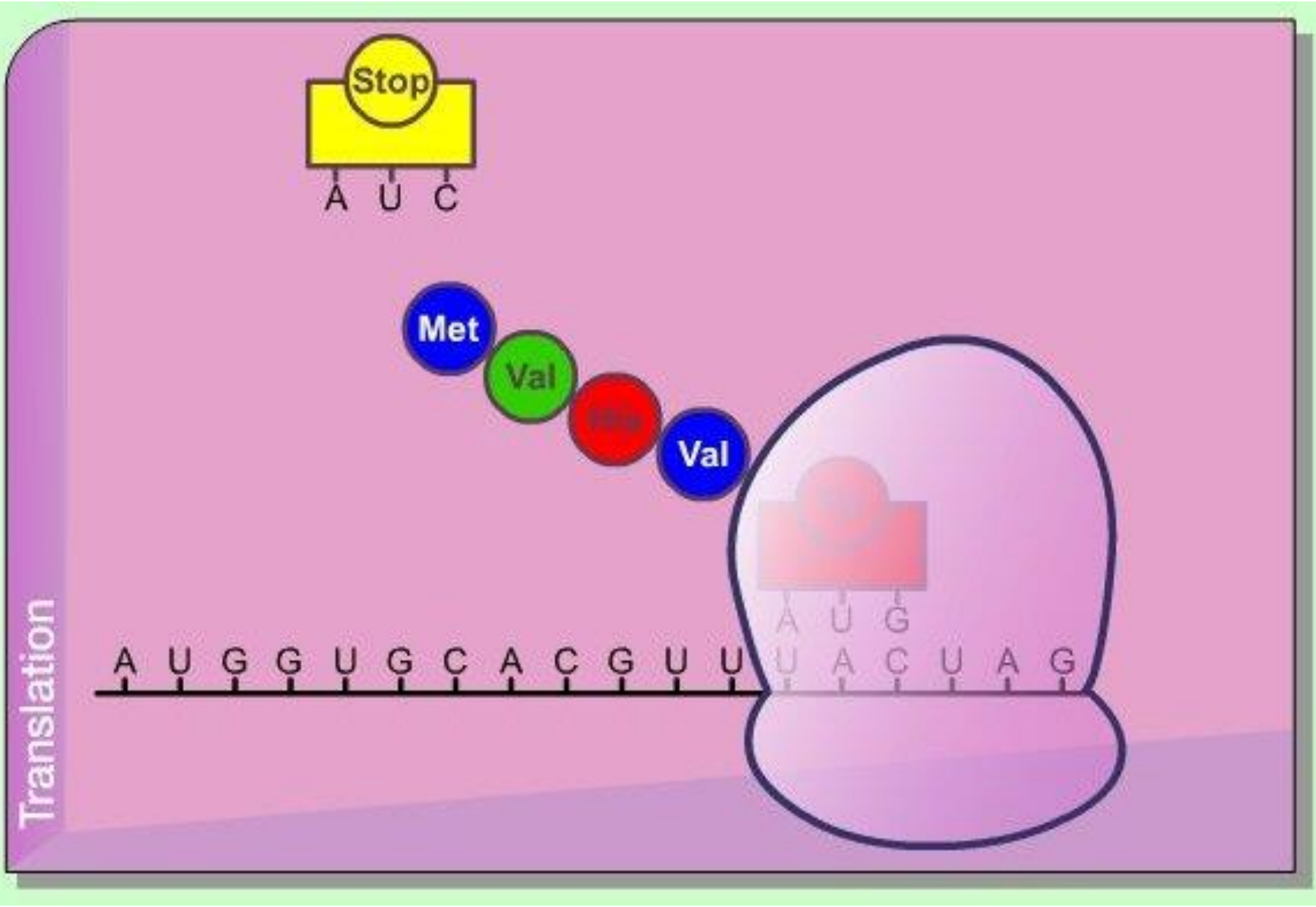
Which anticodon will match the first mRNA codon of AUG?

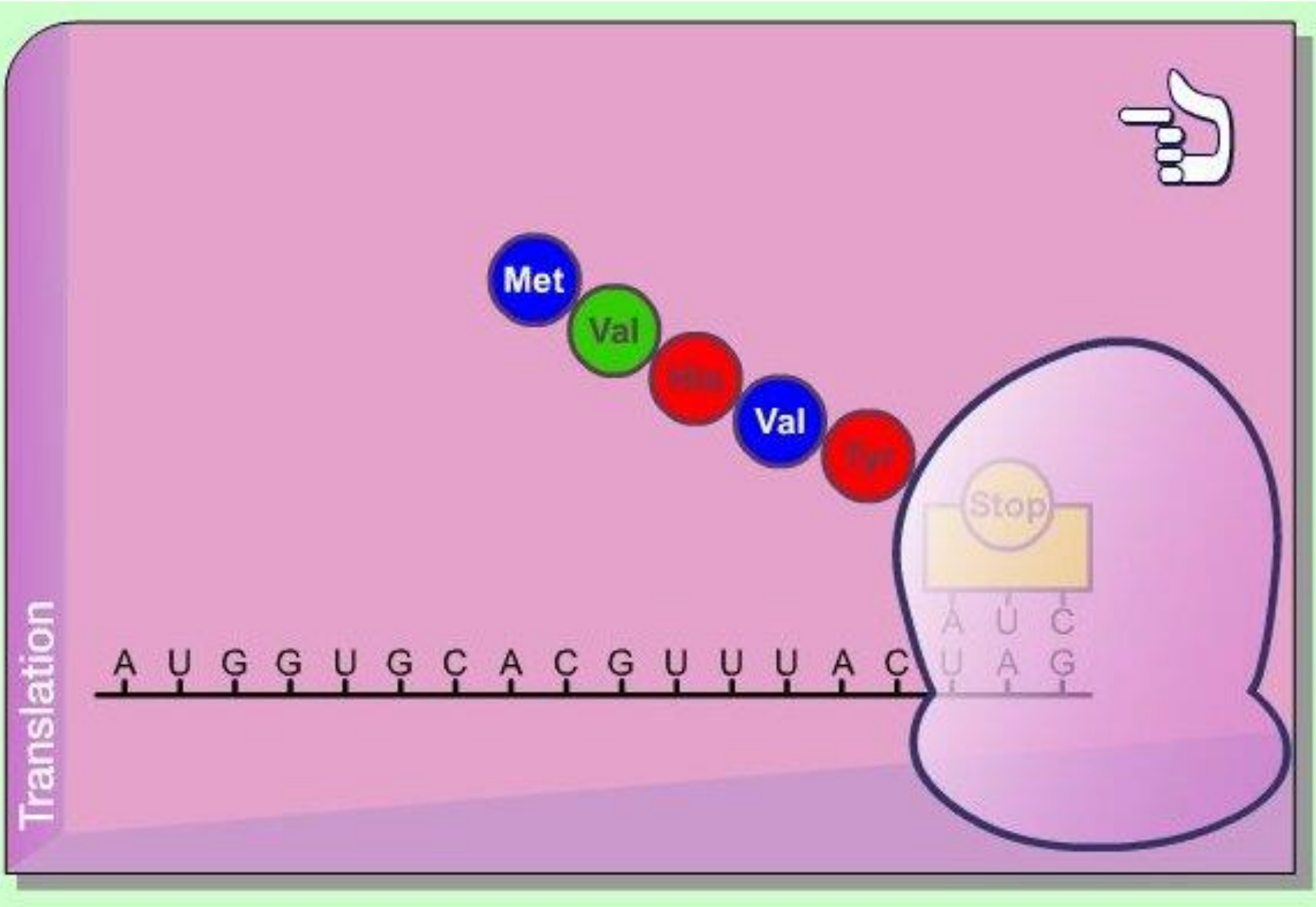

Stop
Val
Val
A U C
A U G
C A C
C A A
G U G
You can see how the anticodon on the tRNA lines up against the corresponding codon on the mRNA and brings the amino acid in the right position. Now carry on building up your protein. You must drag the right anticodon into position.
Met
U A C
A U G G U G C A C G U U U A C U A G
Translation


Stop
Tyr
Val
His
A U C
A U G
C A A
G U G
Met
Val
C A C
A U G G U G C A C G U U U A C U A G
Translation


Stop
Val
A U C
A U G
C A A
Met
Val
G U G
A U G G U G C A C G U U U A C U A G
Translation


Stop
A U C
A U G
Met
Val
Val
C A A
A U G G U G C A C G U U U A C U A G
Translation


Stop
A U C
Met
Val
Val
A U G
U A C U A G
A U G G U G C A C G U U
Translation


Translation
Met
Val
Val
Stop
A U G G U G C A C G U U U A C
A U C
U A G

Energy & ATP

- What is energy?
- How do living organisms store energy for use?

What is Energy?

- Any ideas?
- Energy is the ability to do work.
- There are two states of energy:
  - Kinetic
  - Potential

Kinetic Energy

- The energy of motion.

- Moving objects perform work by making other objects move:

Potential Energy

- Stored energy.

- An object that is not moving may still have the potential to do work – it has potential energy.

Energy's many forms

- There are many different forms of energy.
- Can you name some of them:

Light

Sound

Heat

Atomic

Electrical

Kinetic

Magnetic potential

Gravitational potential

Chemical potential

Elastic potential

Energy…

- Can be changed from one form to another.
  - Eg. From kinetic to electrical, from chemical to heat.
- Cannot be created or destroyed.
- Is measured in Joules.

Without an input of energy…

- Rooms become untidy.
- Uninhabited buildings become derelict.
- Natural processes tend to break down into randomness & disorder.

What has this got to do with Biology?

- Living organisms are highly ordered systems.

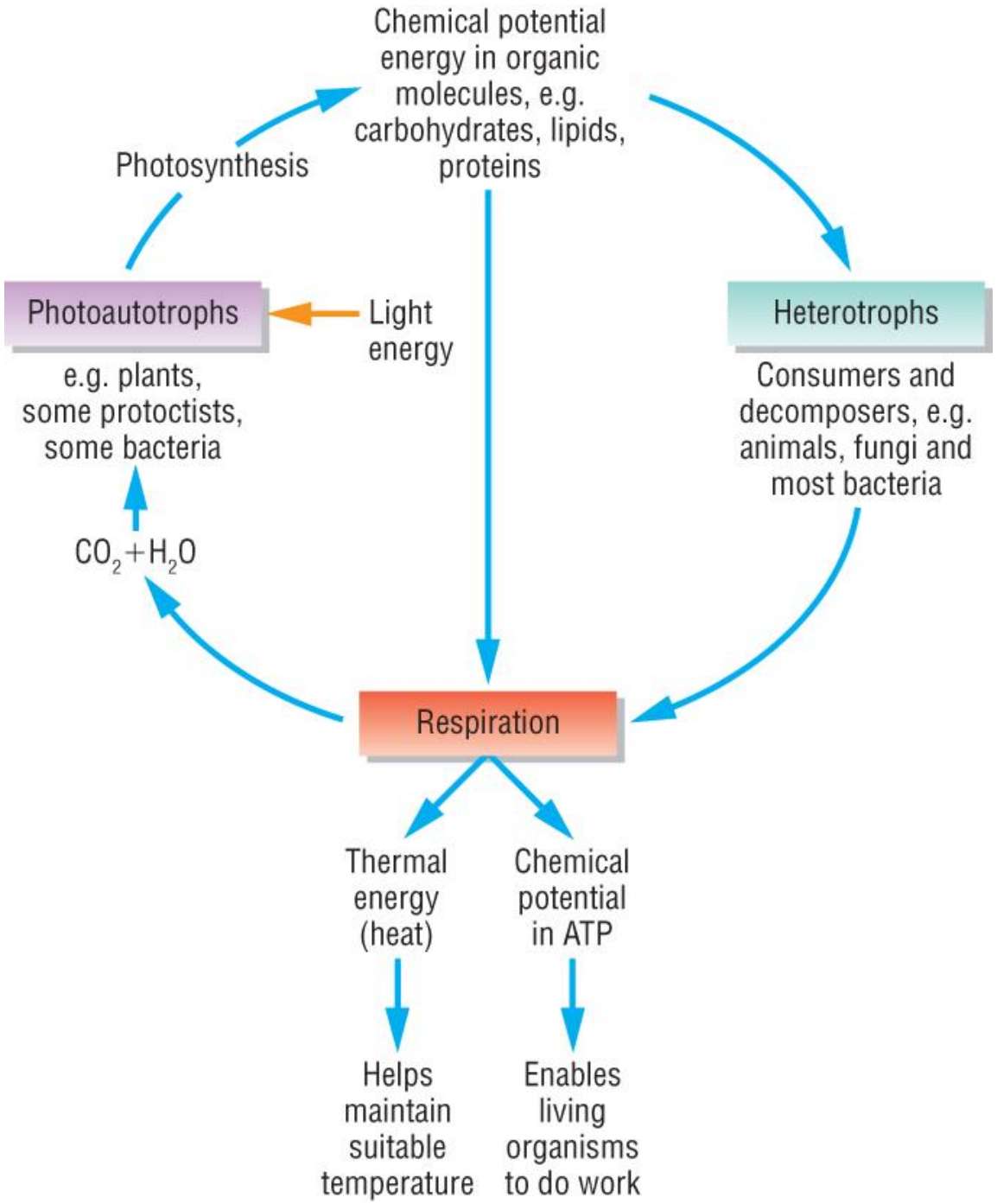
- They need a constant input of energy to stop them from becoming disordered (which would lead to death).

What, specifically, do living things need energy for?

- A year 7 answer would be “for growth & repair”.

- A year 13 answer would be:
  - Metabolism (particularly anabolism).
  - Movement (within an organism & of the organism).
  - Active transport.
  - Maintenance, repair & cell division.
  - Homeostasis (particularly of body temperature).
  - Secretion of chemicals (Eg. Hormones).

Where does our energy come from?

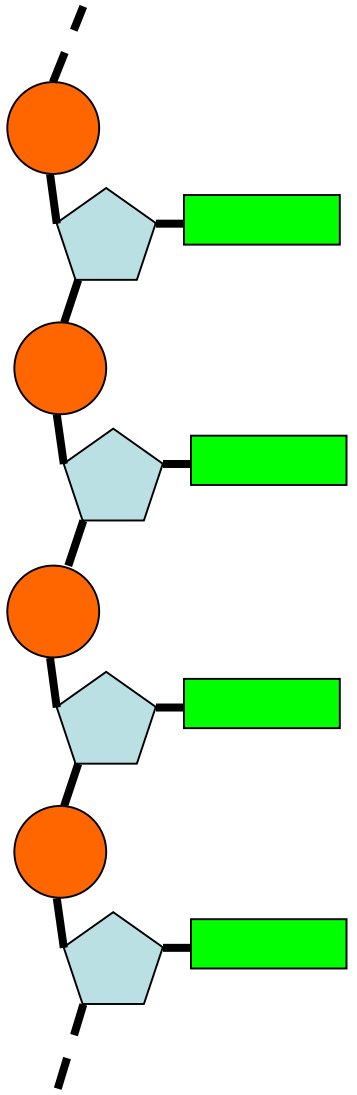


ATP & other TLAs

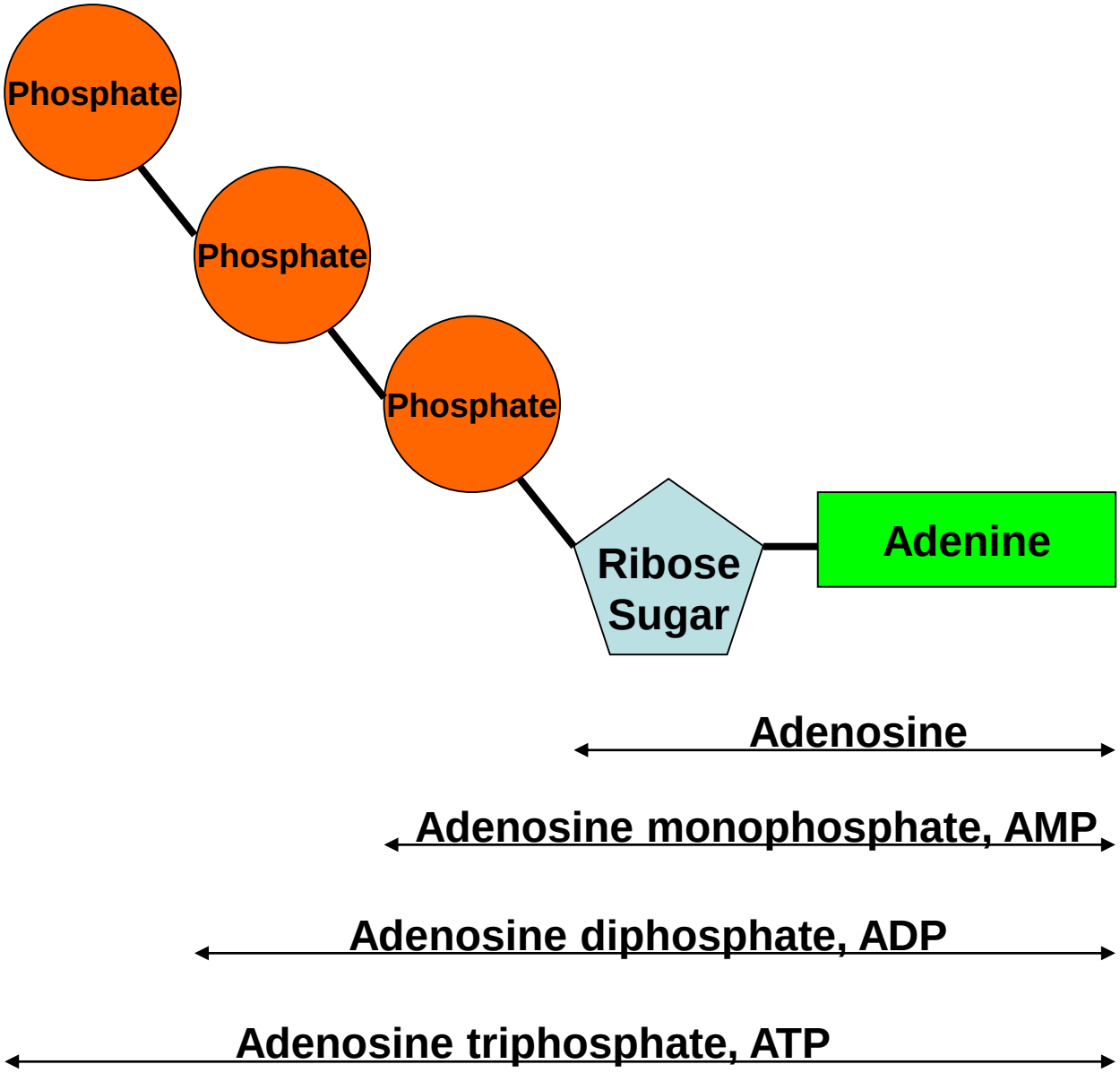
- Adenosine Triphosphate (ATP) is the main energy currency of living cells.
- ATP is a small, water soluble molecule.
  - It is therefore easily transported around the cell.
- ATP stores energy as chemical potential energy.
  - Think of it as a tiny loaded spring.

The Structure of ATP

- Think back to the work on nucleic acids.
- This is RNA with its sugar-phosphate backbone and nitrogenous bases.
- The sugar is ribose and the bases are Adenine, Uracil, Cytosine or Guanine.



The structure of ATP

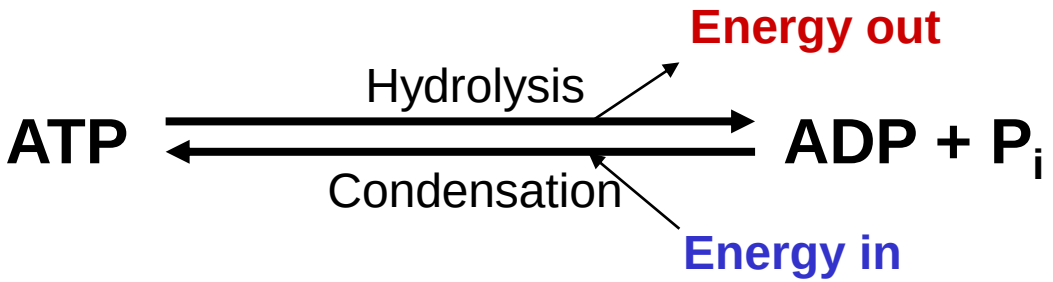


How does ATP store energy?

- Each phosphate group is very negatively charged.
  - So they are all straining to get away from each other.
  - The covalent bonds holding them together are easily broken.
  - When they break, P_i is released along with $30.6kJmol^{-1}$ of energy for each of the first two phosphates removed.
  - it is literally like a loaded spring waiting to be released.

Synthesis of ATP

- The conversion of ATP to ADP is reversible.
  - Energy from respiration can be used to combine ADP with P_i to re-from ATP.
    - This reaction is called phosphorylation and is an example of a condensation reaction.
    - It is catalysed by ATP synthase or ATPase.



The role of ATP

- The instability of ATP's phosphate bonds makes it a rubbish long term energy storage molecule.
  - Imagine a garage full of loaded mousetraps all set to snap closed at the slightest touch…
  - Fats and carbohydrates are better for this.
- ATP is the intermediate energy source.
  - So the cell does not need large quantities of ATP.
  - It maintains only a few seconds supply.
  - ATP is rapidly reformed so a little goes a long way.

Exam Question:

- Describe the structure of ATP.

.....

.....

.....

.....

.....

[Total: 4 marks]

Mark Scheme:

accept labelled sketch diagram for marking points below

- nitrogenous base / purine;
  adenine;
  pentose / 5 carbon, sugar;
  ribose;
  three, phosphate groups / Pi; **R** phosphate molecule
  phosphorylated nucleotide;
- **A** adenosine as an alternative to adenine **plus** ribose
- **4 max**