

# Unit Five

## **Genetics and Evolution**

### **Part IV**

# Protein synthesis

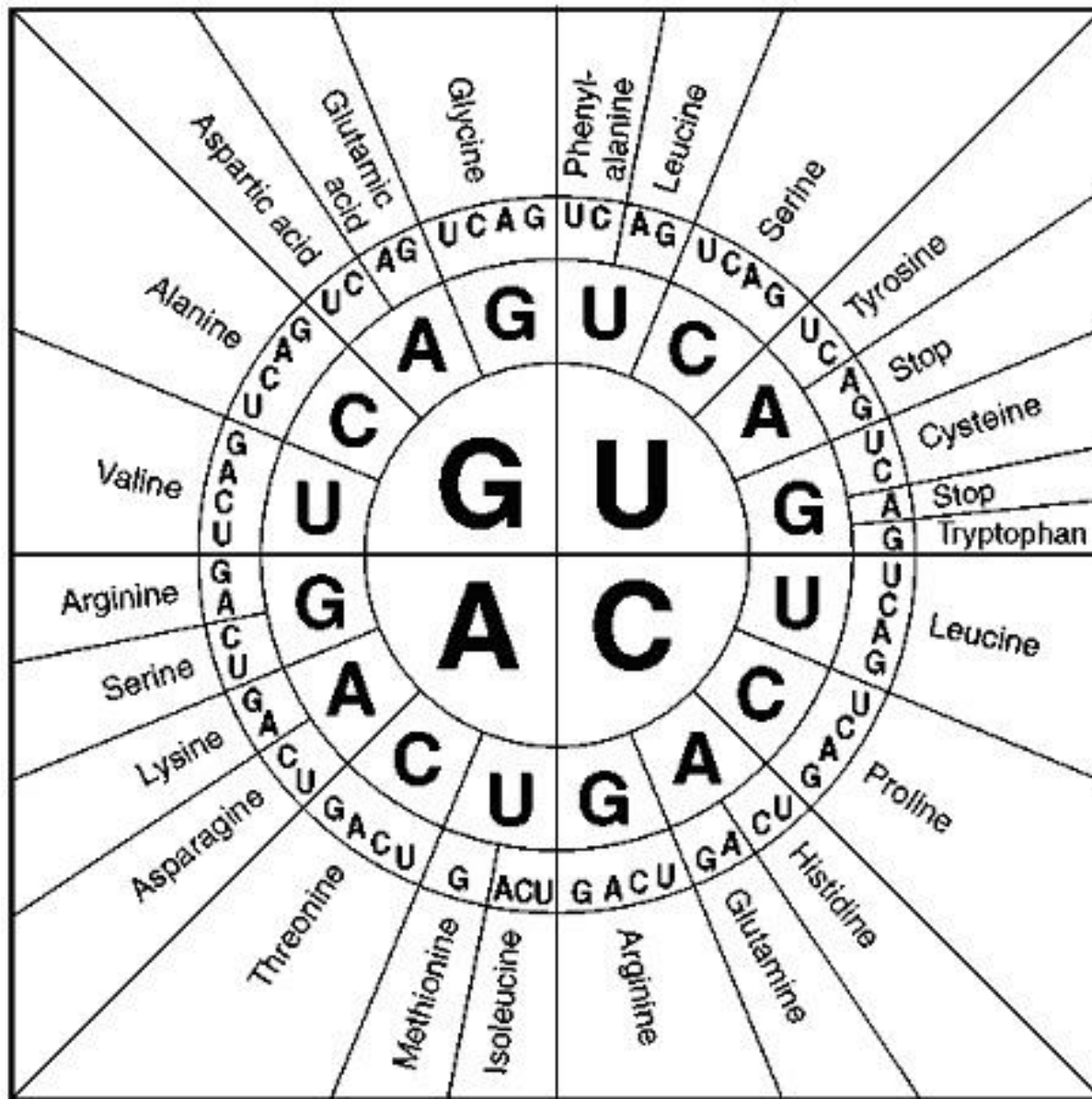
- Code for protein synthesis is specified by DNA and has to be sent to ribosome. DNA is a huge molecule and remains in nucleus to assemble amino acids in the correct sequence to form protein.
  - Events during protein synthesis
    - i. Transcription – DNA code for protein is rewritten in a molecule of messenger RNA (mRNA)
    - ii. mRNA travels from nucleus to ribosome
    - iii. Free amino acids are transported from cytoplasm to ribosome by transfer RNA (tRNA) molecules
    - iv. Ribosome read mRNA code and assembles amino acids presented by tRNA into a protein by a process = translation. Translation – is process in which mRNA code is converted into a sequence of amino acids
- DNA code → mRNA codon → protein/ polypeptide

# Genetic code

- The genetic code is held in the DNA molecule. It is because of the nucleotides sequence in the DNA molecule made a gene that codes for protein to that each amino acid in the protein is coded for by a triplet /sequence of three bases. Hence, a gene is a sequence of base triplets in the DNA molecule that carries a code for a protein.

1. Since there are 4 bases, there is  $4^3 = 64$  possible triplet codes /amino acids/ but only 20 amino acids are used to make all different proteins. None of them is spare or redundant.
2. Only one strand of a DNA molecule carries the code for proteins (It is called sense strand or coding stand) and the other strand is non-coding or antisense strand.
3. Most amino acids have more than one code, only methionine and tryptophan have one code.
  - Arginine has six codes

4. Three triplets (TAA, TAG, and TGA) do not code for amino acids and they are called stop codons. stop codes signify the end of the coding sequence
5. Degenerate code – the DNA code is non-overlapping codes i.e., each triplet is distinct from all other triplets.
6. The genetic code is also a universal code i.e. the triplet code TAT in the DNA code for amino acid tyrosine in human, redwood tree, bacterium or in any organism E.g. ACC – threonine, GGG-glycine



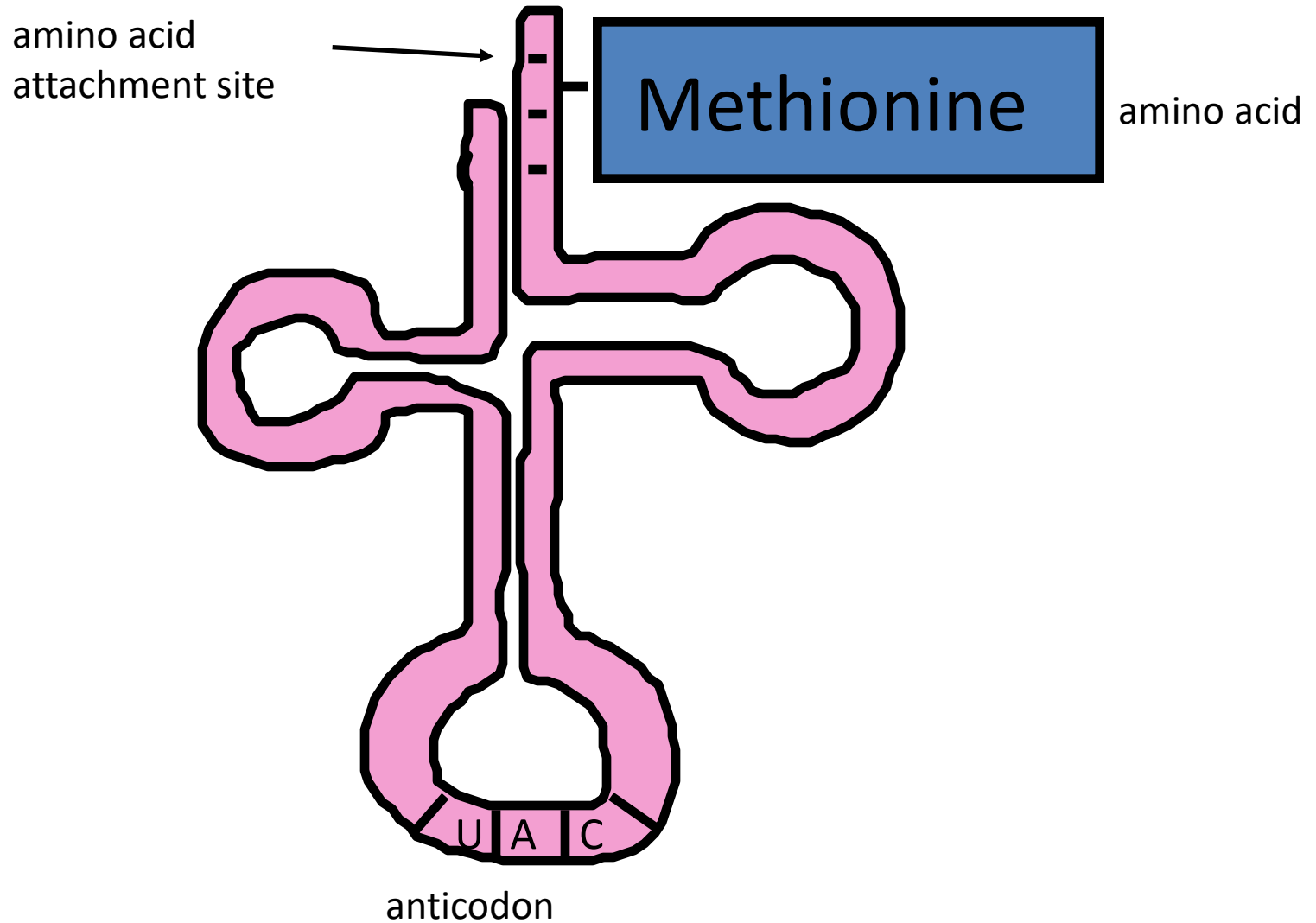
Genetic code

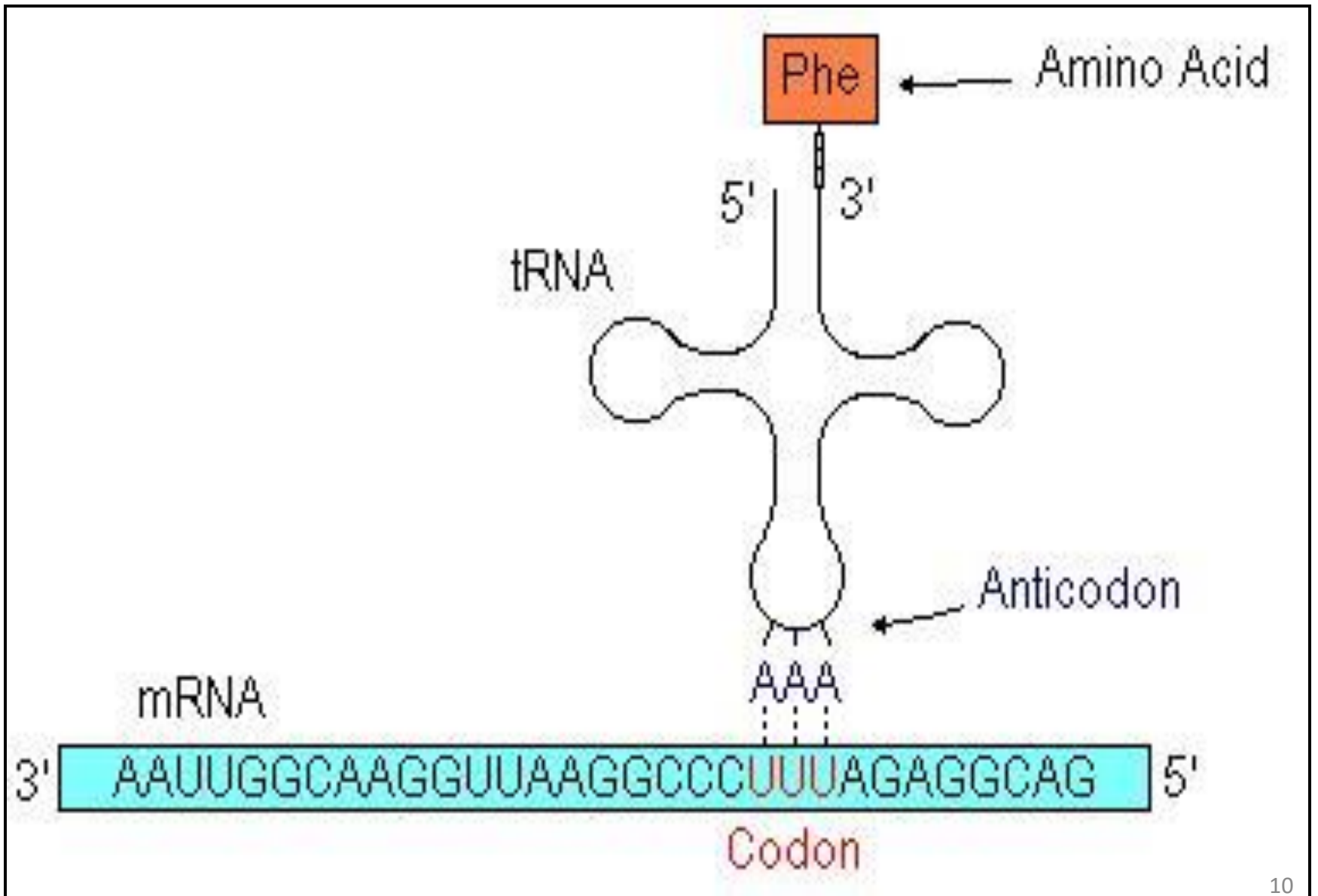
N.B. It is not just the base that matter but the sequence, e.g. ATT codes of different amino acid from TTA

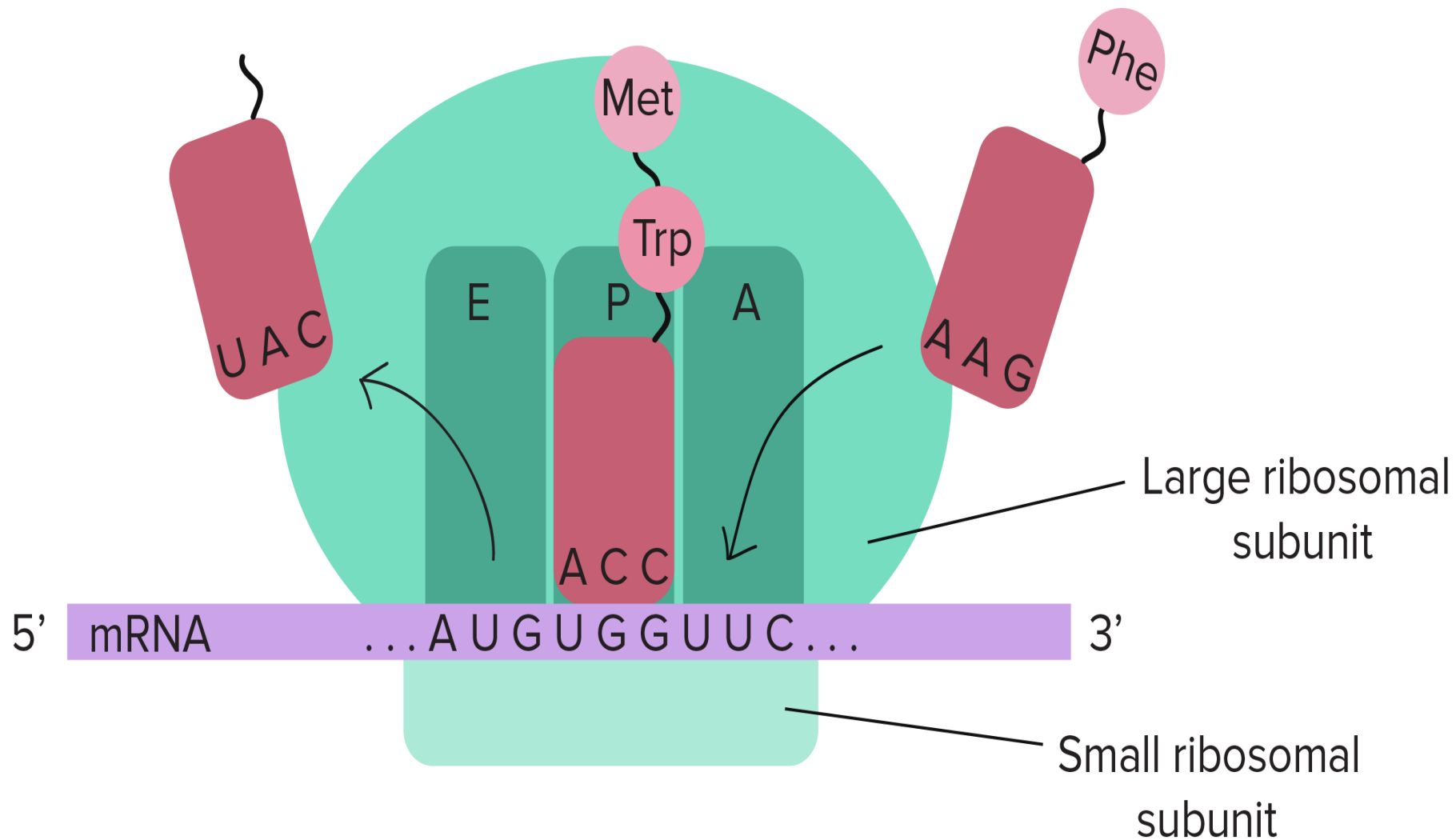
- The enzyme DNA-dependent RNA polymerase binds with a section of DNA next to the gene to be transcribed. Transcription factors activate the enzyme. The enzymes — unwind and separate the strands of a DNA molecule. The polymerase assembles free RNA nucleotides on the complementary strand (antisense strand). mRNA (transcribed RNA) leaves the DNA; the strands of DNA rejoin & re-coil.
- N.B. The mRNA molecule now contains the code for the protein that was held in the DNA of the genes

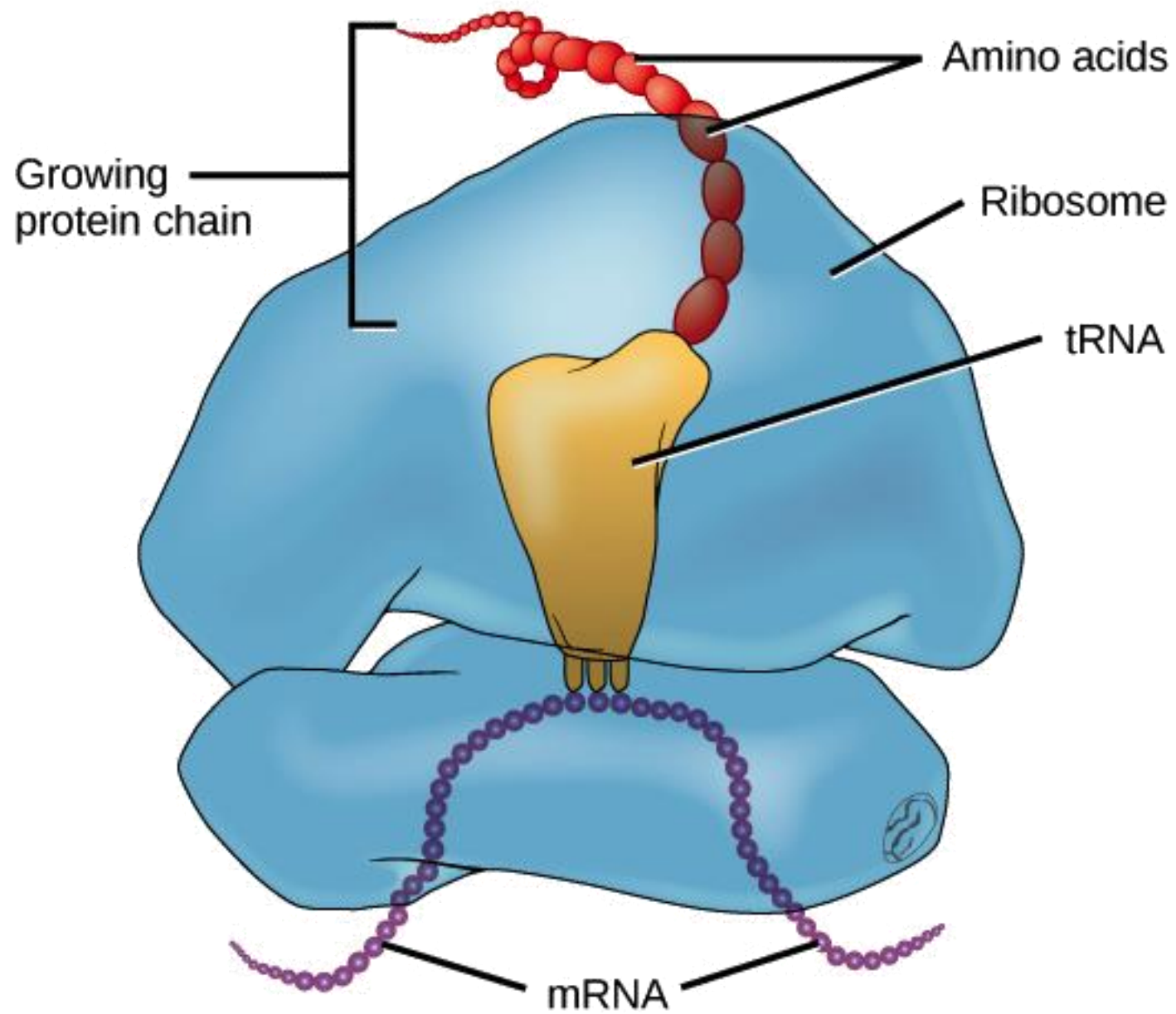
- Translation of mRNA code into a protein depends on the interaction within a ribosome between mRNA and tRNA. All tRNA molecules have same basic structure. The "cloverleaf" configuration of the molecules has at one end a triplet of bases called anticodon. The anticodon is a triplet on tRNA. The other end of tRNA molecule has an attachment site for the aminoacid that is specified by the mRNA codon.
- Ribosomes are made from ribosomal RNA and proteins organized into large & small subunits. Within ribosome, there are three sites called A, P and E sites.

# Transfer RNA (tRNA)









# Events during translation of proteins

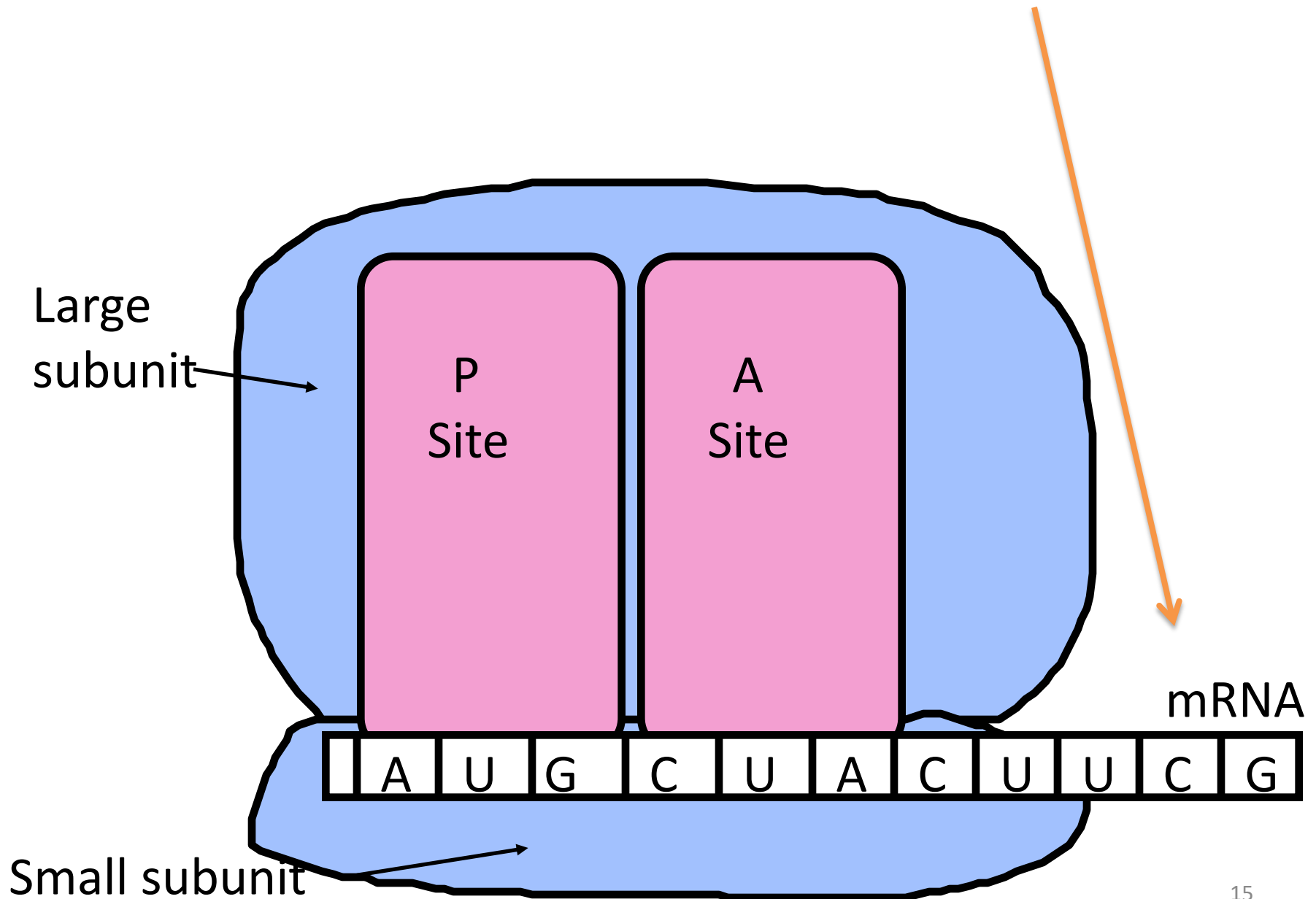
- The first two codons of the mRNA enter the ribosome and tRNA molecules (with amino acid attached) that have complementary anticodons to the 1st two codons of the mRNA bind to those codons. A peptide bond forms between amino acid carried by two tRNA molecules and dipeptide is transferred to the tRNA in the A-site. The Ribosome moves along the mRNA by one codon bringing the 3rd codon into the ribosome.

- At the same time the free tRNA exits the ribosome from the E-site and tRNA with the dipeptide moves into the P-site. A tRNA with complementary anticodon binds with the third codon and brings its amino acid into position next to the 2nd. A peptide bond is formed between 2nd and 3rd amino acid. The whole process is repeated until a "stop" codon is in position and translation is stopped.

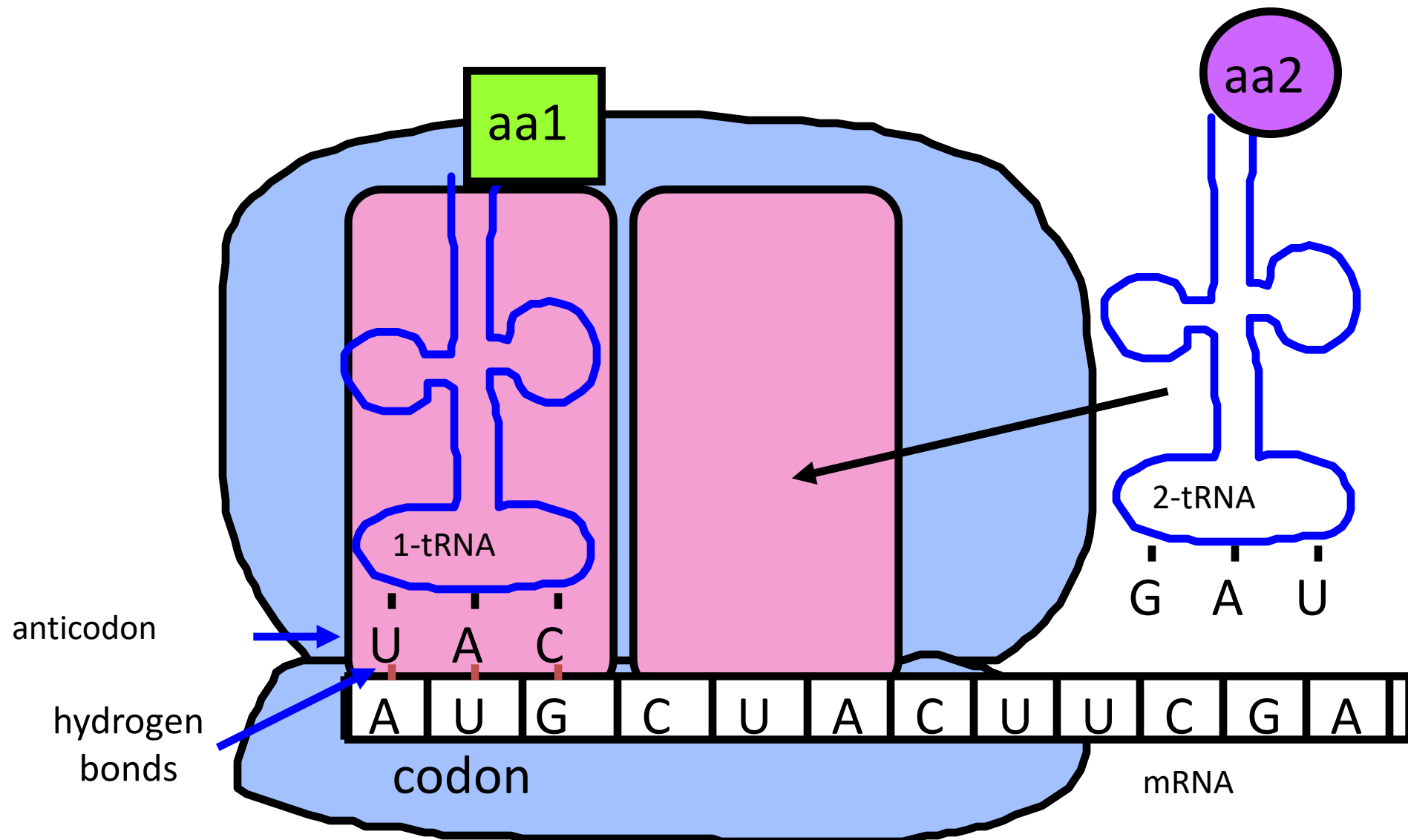
Note: - TGA, TAA and TAG – are stop codons.

N.B. The translation of the mRNA code into a protein molecule requires energy that comes from hydrolysis of GTP /guanoisine triphosphate/ not ATP

# mRNA Codons Join the Ribosome



# Initiation



# Elongation

peptide bond

aa1

aa2

aa3

1-tRNA

2-tRNA

3-tRNA

G

A

A

U

A

C

G

A

U

A

U

G

C

U

A

C

U

U

C

G

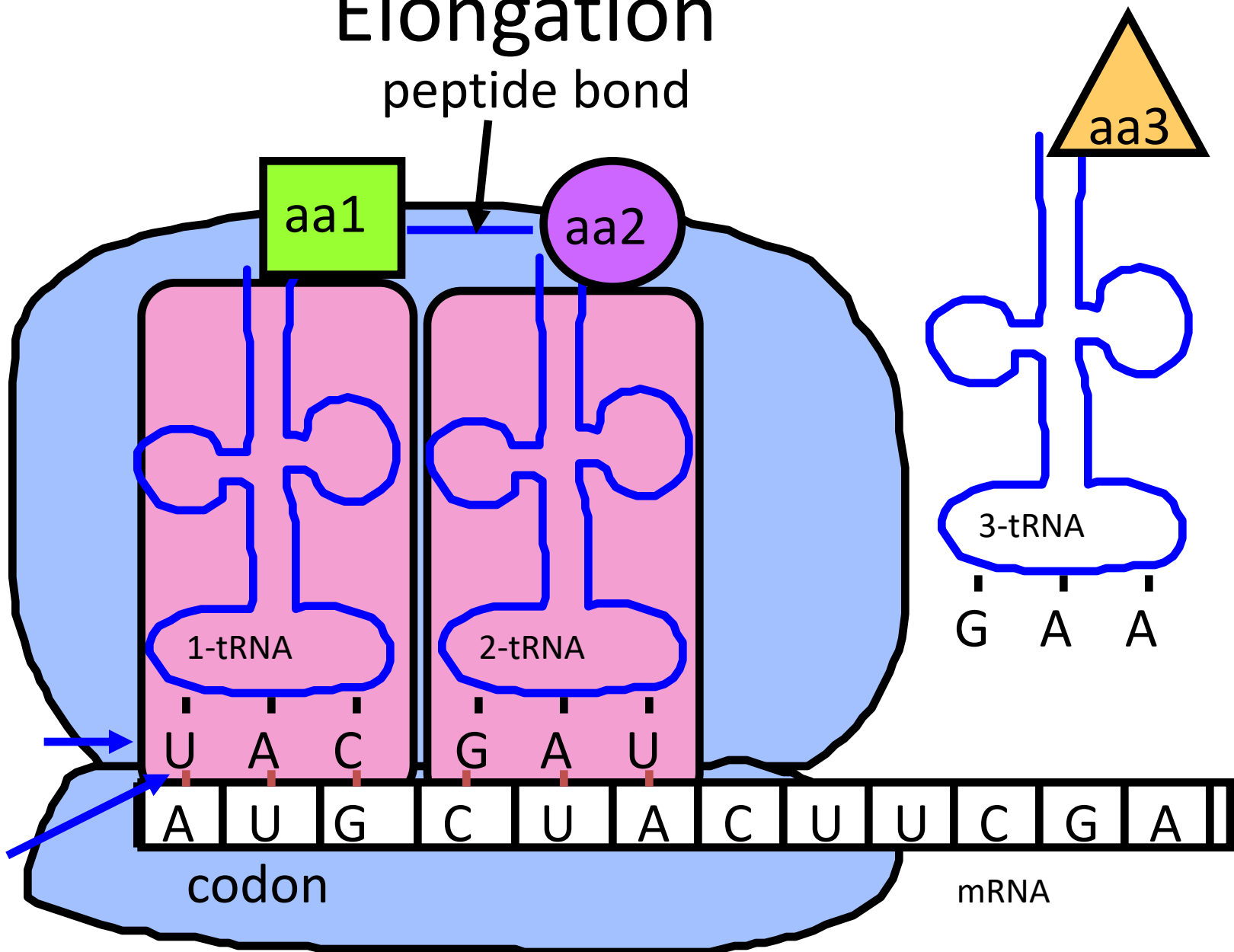
A

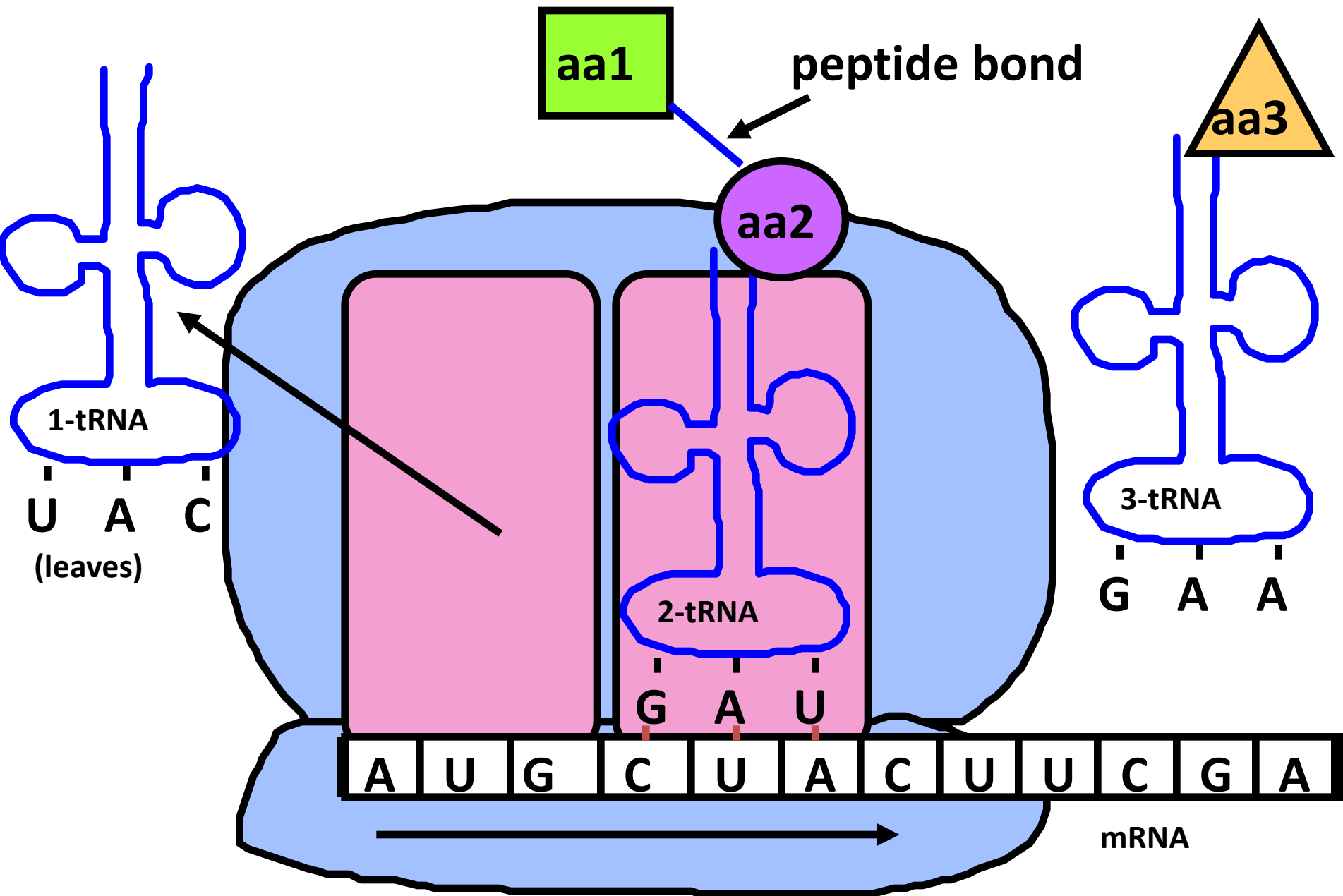
codon

mRNA

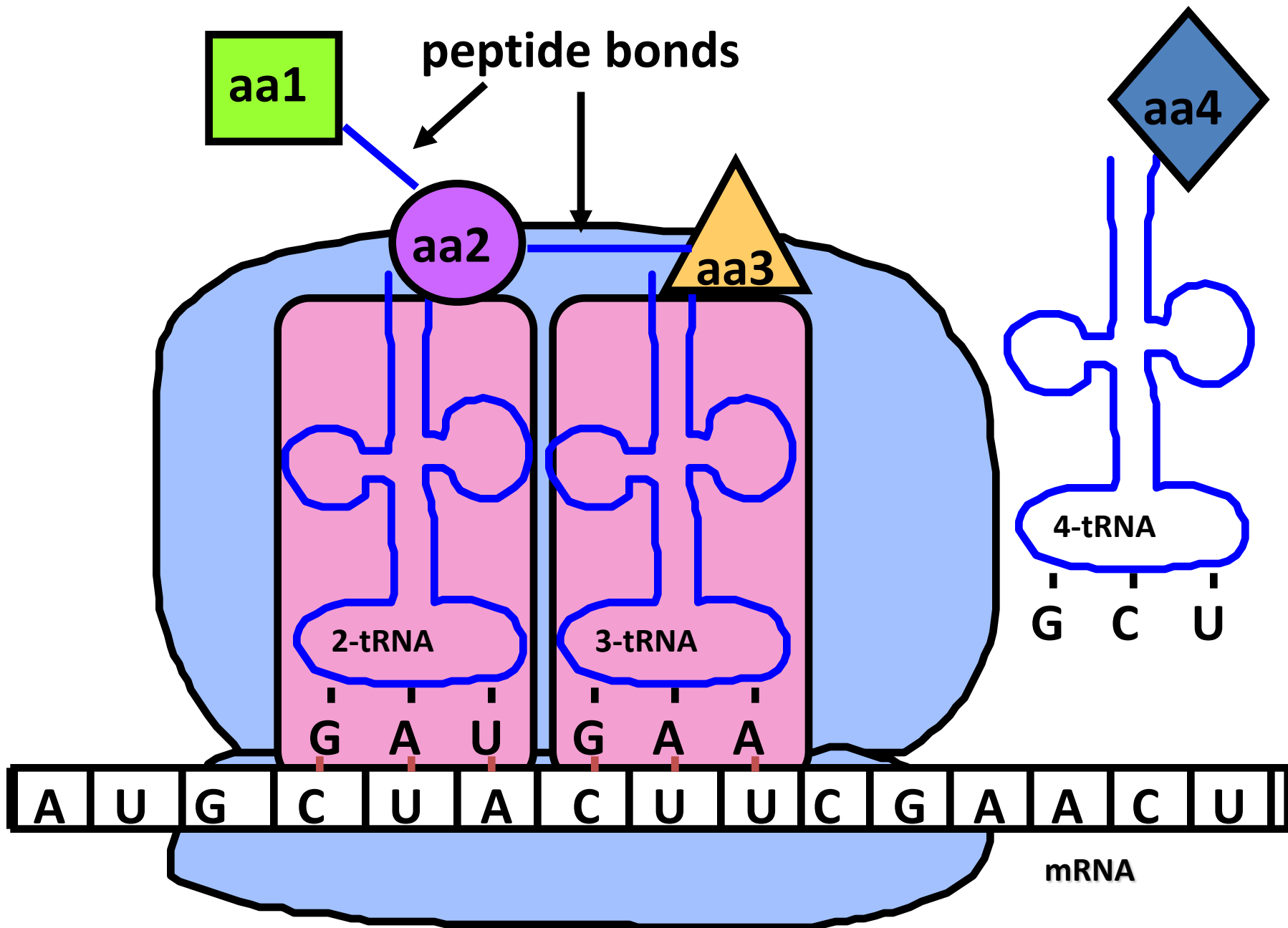
anticodon

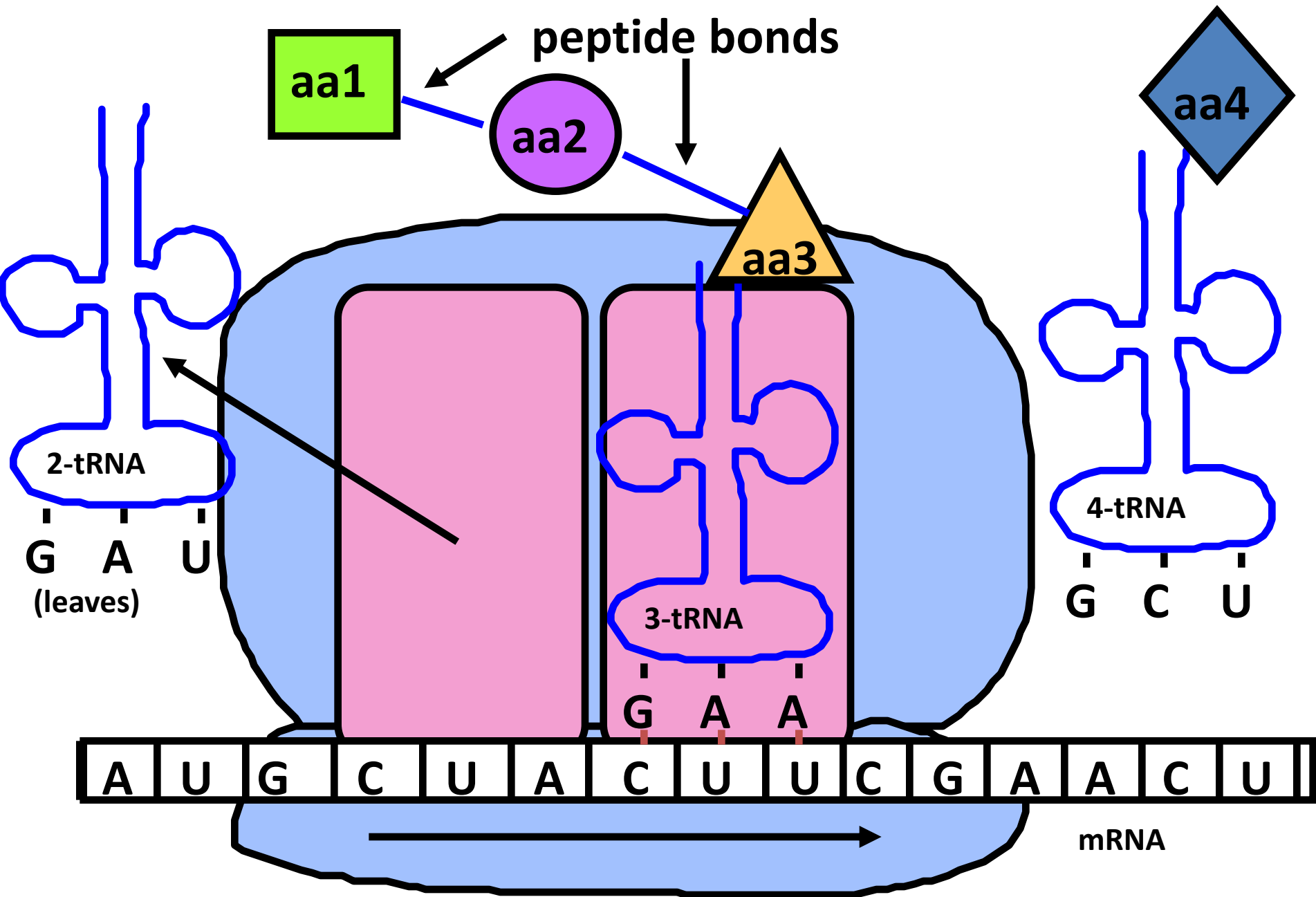
hydrogen bonds



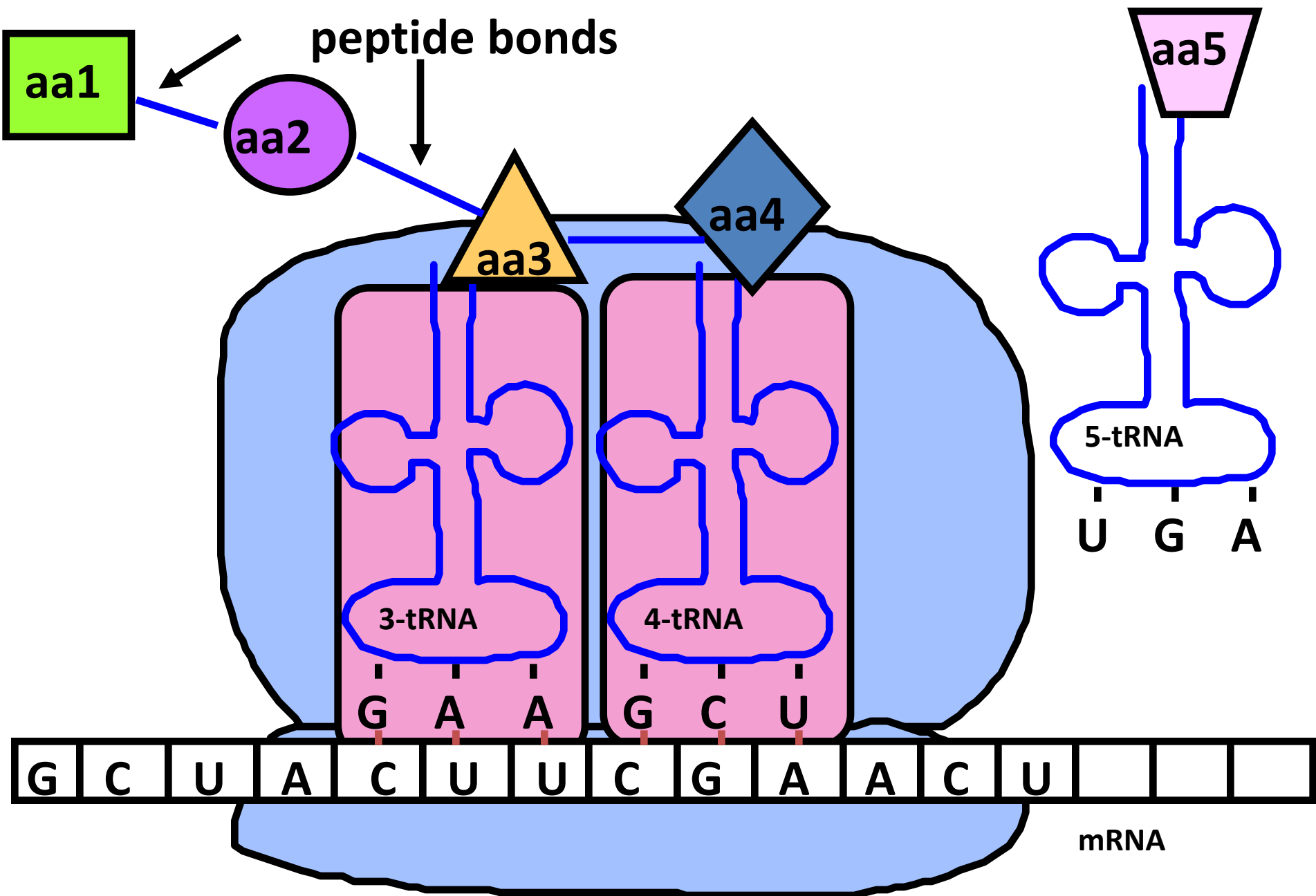


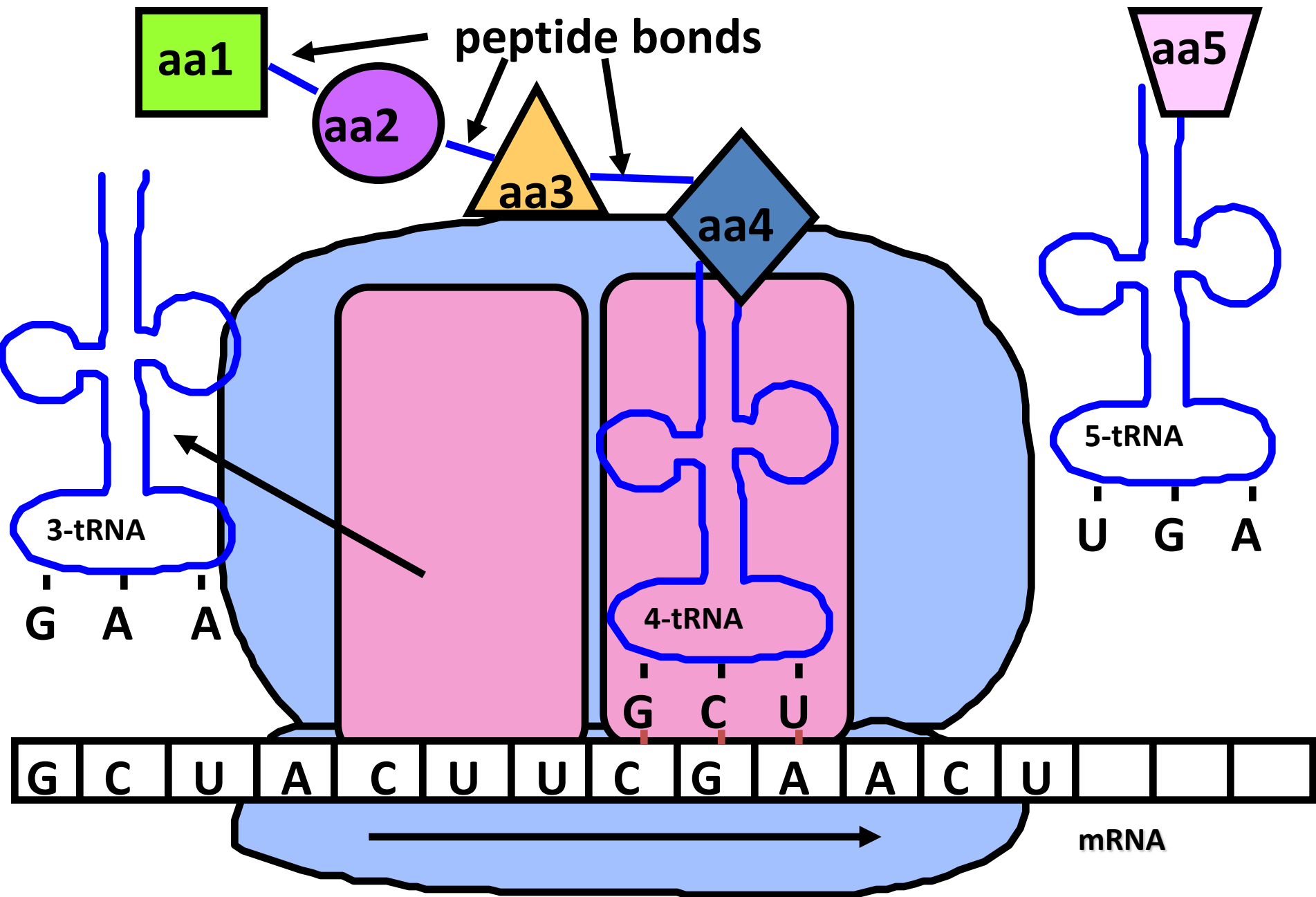
Ribosomes move over one codon



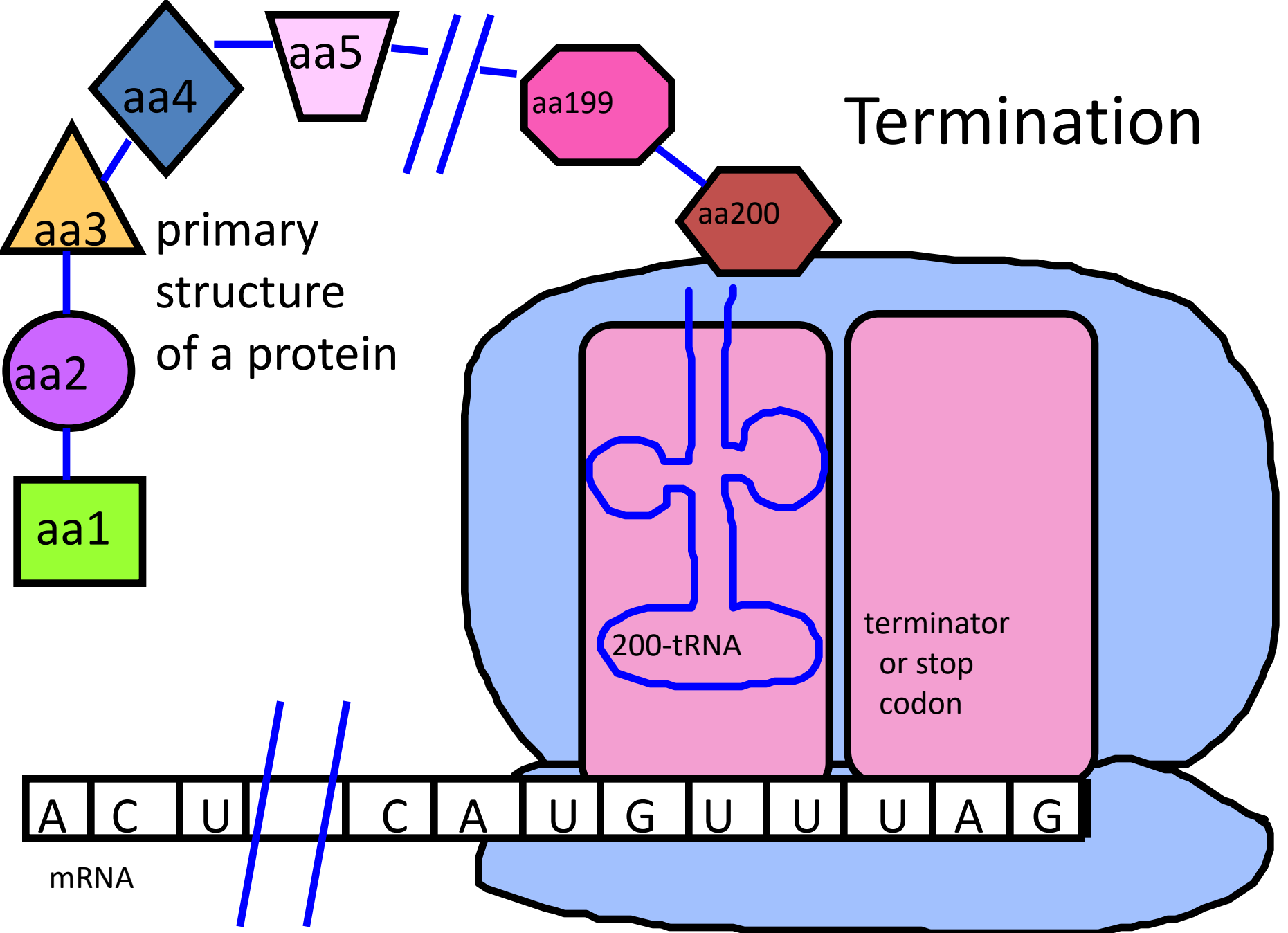


Ribosomes move over one codon



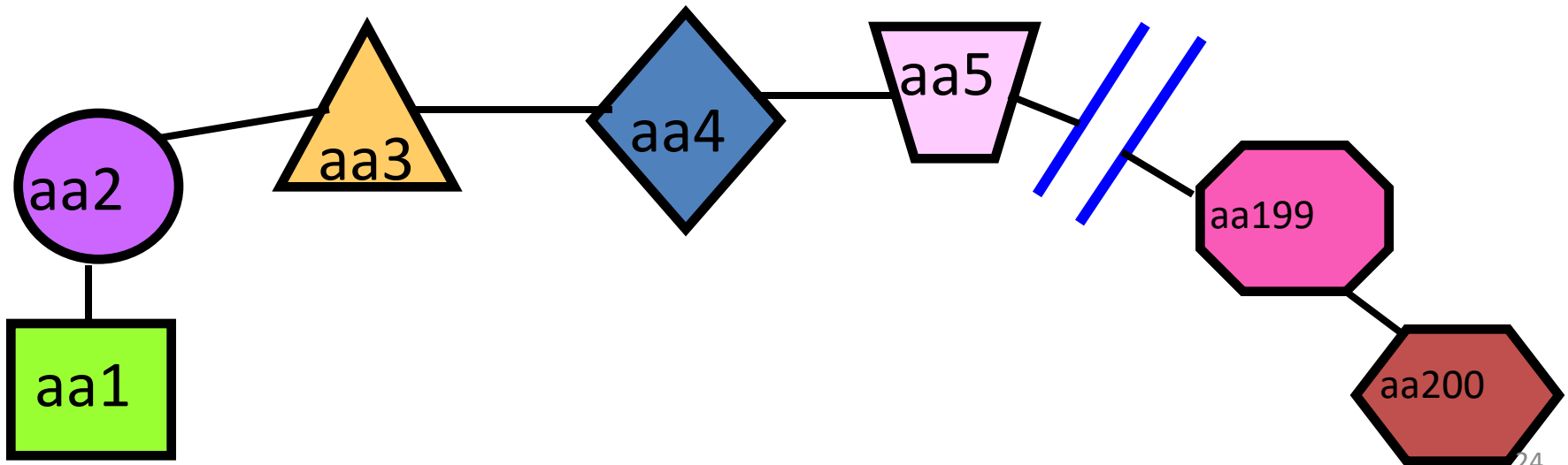


Ribosomes move over one codon



# End Product –The Protein!

- The end products of protein synthesis is a primary structure of a protein
  - ✓ A sequence of amino acid bonded together by peptide bonds



- Though it is similar to eukaryotes, there are some differences like: Prokaryotic cell have no nucleus. Prokaryotic mRNA does not need post-transcriptional process because it only contains exons (coding genes) not introns (non-coding genes). Transcription and translation are coupled - mRNA translated at one end of ribosome while it starts transcribing from DNA at other end.

- Transamination: - is a process of amino group of an amino acid is removed and transferred to a keto acid, then it becomes a different amino acid/keto acid E.g. pyruvic acid (keto acid) → alanine (amino acid) - by transamination.
- Note. Not all amino acids are produced by transamination only those we obtain from our food. They are called essential amino acid.

# Control of Gene expression

- Genes are switched on by "transcription factors"- are proteins that bind to a regulatory sequence of DNA near to the gene they influence. They operate in the following way: The transcription factors bind to a promoter sequence of DNA near the gene to be activated. RNA polymerase binds to the DNA/ transcription factor complex. The RNA polymerase activated and moves away from the DNA along the gene. The RNA polymerase transcribes the antisense strand of the DNA and the gene is now being expressed.

- Like transcription factors that promote gene expression, there are factors to repress (switched off) gene action. Short interfering RNA (siRNA)
  - are unusual-very short
  - only 21-23 nucleotides
  - double stranded
  - They don't act on the gene itself, but interfere/silence the mRNA once it has been transcribed from DNA.
  - Is post transcriptional interference
- If mRNA is prevented from translating its Codons into amino acid then the protein for which the gene codes for cannot be built (silenced).

# Mutations

- Mutation is the alteration of the nucleotide sequence of the genome of an organism, virus, or extrachromosomal DNA.
  - Mutation could occur spontaneously (accidentally) during duplication.
  - They are rare events.
  - Each cell contains  $6 \times 10^9$  /billion/ base pairs.  $\frac{1}{50 \times 10^6}$  occurrence
  - Each new cell has an average 120 mutations. But
    - Most mutations detected & repaired
    - 95% of our DNA is non-coding, most mutation unlikely to affect coding gens.
  - Rate of mutations can be increased by:-
    - Carcinogenic - chemical in tobacco smoke
    - High energy radiation- ultraviolet radiation, x- ray

- There are many different ways that DNA can be changed, resulting in different types of mutation as described below:
  1. Point mutations- changes that involves a single base. There are several types of point mutations, some of these are:
    - Substitution- one base is replaced by other base
    - Addition– an extra base is added
    - Deletions – a base is missed out during DNA replication.
  2. Chromosomal Mutations- situation where part /segment/ of a chromosome sequence of DNA is disturbed/ a chromosome is missed/added. Types of chromosomal mutations:

- Euploidy: having a chromosome number that is an exact multiple of the haploid number
  - Polyploidy: the condition in which a normally diploid cell or organism acquires one or more additional sets of chromosomes. E.g – Triploid, Tetraploid
- Aneuploidy – is a condition where an organism/a cell lost from or added to one or more chromosomes to/the normal set of chromosome
  - $2n+1$  = trisomy/47 chromosomes, e.g. Down's syndrome
  - $2n-1$  = monosomics – turner syndrome/45chr.
  - $2n+1+1$  = double trisomy
  - $2n-2$  – nullisomic, organisms that loss one homologous chromosome.
- Gidu syndrome = mental retardation – caused by part of deletion of chromosome number 5 of man.

# Consequence of gene-mutations

- Mutations on body cell (non- sex cell) cannot be inherited but may result in one of the following:
  - harmless
  - damage the cell
  - kill the cell
  - Make cell cancerous- which might kill the person.
- Mutations in different genes will obviously produce different effects but two types of gene are important in regulating cell division and preventing the formation of a tumor.

a. Proto-oncogenes: when proto-oncogenes mutate, they often become active oncogenes which stimulate cell to divide in an uncontrolled manner.

b. Tumor-suppressor genes: recognize this uncontrolled cell division and act to suppress cell division.

- If these genes mutate and become inactive, a tumor will form as uncontrolled cell division continues.
- Tumor-is a mass of cells created when cell replication gets out of control and cause cancer.

# Manipulation of DNA

## Genetic engineering

- Genetic engineering is a process by which the genome of an organism is altered, usually by having extra (foreign) gene from different organisms, and the organism is termed genetically modified organism (GMO), transgenic organism or genetically engineered organism.



- Genetic engineering is early done on Bacteria, to produce useful products like:
  - Insulin, antibiotics, washing enzyme
  - Enzyme for food processing industry
  - Human growth hormone
  - Vaccines-Hepatitis B
  - Bovine somatotrophin, high yield milk and muscle development in cattle.

- Plants are also genetically modified:
  - To absorb more CO<sub>2</sub> – global warming
  - Disease (drought) resistant
  - Improved yield
  - To produce specific product E.g. golden rice produce beta-carotene (in vitamin 'A') prevent night blindness.

- Moreover, **animals are genetically modified** for the following purposes
  - high yield of protein, high growth rate
  - Specific products eg. insulin,
  - Detection of water pollution = glofish glow in the dark b/c they have had bioluminescent gene from jelly fish.
  - Genetically modified salmon and Tilapia fish grow bigger and faster.

- Some other potential application of genetic engineering are:
  - Disease could be prevented by detecting defected genes.
  - To treat infectious diseases by implanting antiviral proteins (antibodies).
  - To produce plants and animals that have high growth rate and reduced susceptibility to disease – reduce use of fertilizers and pesticides.
  - Animals and plants can be 'tailor made' to show desirable characteristics

# ABO blood groups and Rh Factors

- Early experiments with human blood transfusion often resulted in the death of the patient for unknown reasons. In 1901, it was discovered that there were three blood types, A, B, and O, and that mixing blood from different types caused an immune response that resulted in clumping. Type AB is rare and was discovered later.

- ABO Blood Type: An individual's red blood cells will contain **proteins** of type A, or B, or both, or neither.
- The body produces antibodies that will attack any foreign type. Alleles of types  $I_A$  and  $I_B$  are dominant over type  $i$ .

# Types of blood

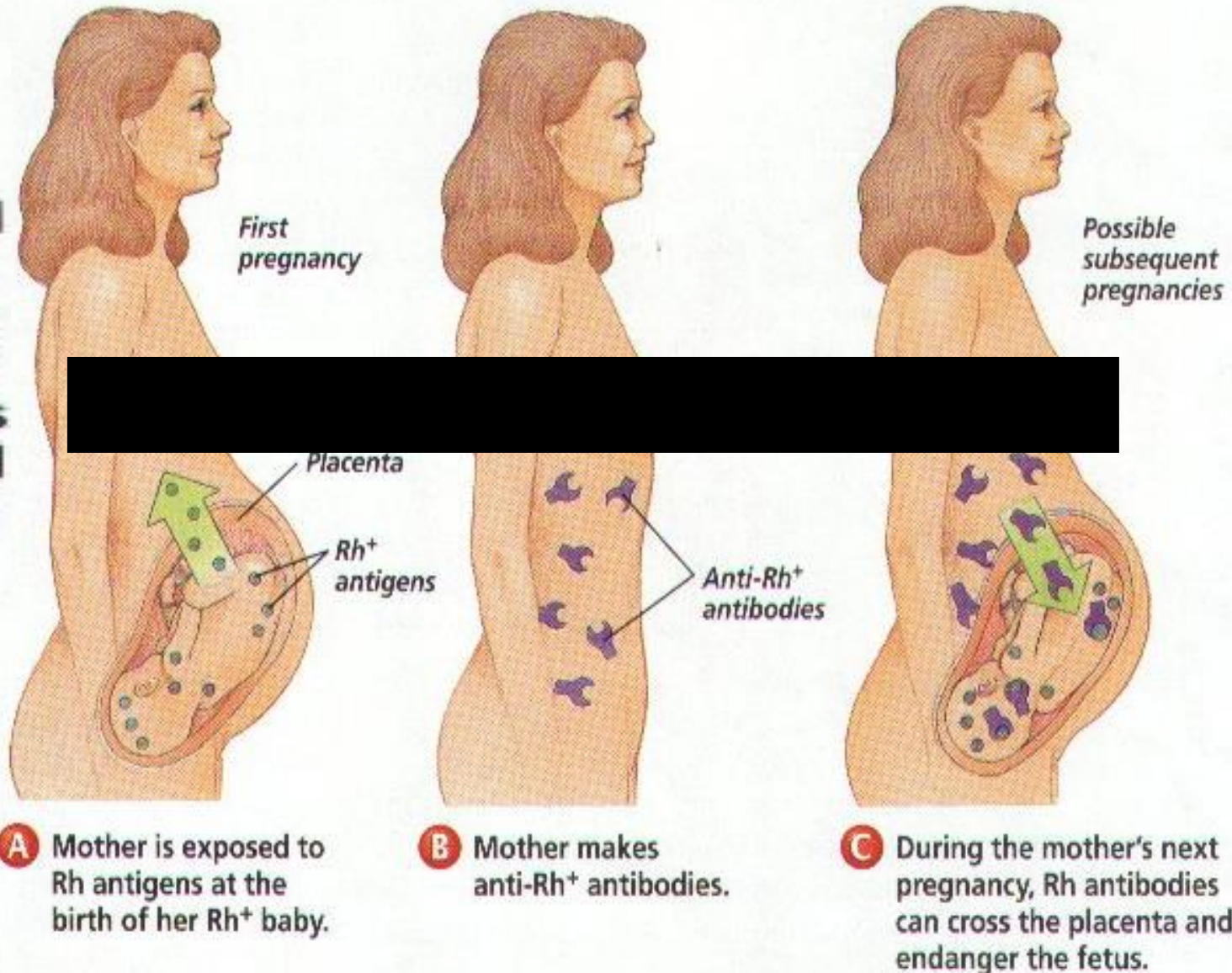
| Genotype  | Blood Type | Antigens | Antibodies        | Donate To   | Receive From |
|-----------|------------|----------|-------------------|-------------|--------------|
| ii        | Type O     | None     | Anti-A and Anti-B | A, B, AB, O | O            |
| $I_A I_A$ | Type A     | A        | Anti-B            | A, AB       | A, O         |
| $I_A i$   | Type A     | A        | Anti-B            | A, AB       | A, O         |
| $I_B I_B$ | Type B     | B        | Anti-A            | B, AB       | B, O         |
| $I_B i$   | Type B     | B        | Anti-A            | B, AB       | B, O         |
| $I_A I_B$ | Type AB    | A and B  | None              | AB          | A, B, AB, O  |

- Rh Factor (D antigen): The Rh factor, the second most important blood group system after the ABO blood group system, was first discovered in Rhesus monkeys.
- The Rh factor is inherited independently from the ABO blood type. Genotypes for the Rh factor are  $+/+$ ,  $+/-$ , and  $-/-$ . People who are  $+/+$  or  $+/-$  possess the Rh(D) antigen and test as Rh positive. People who are  $-/-$  do not possess the Rh(D) antigen and test as Rh negative.

| Genotype | Phenotype | Blood Proteins | Blood Antibodies | Donate To  | Receive From |
|----------|-----------|----------------|------------------|------------|--------------|
| +/+      | Rh+       | Rh(D) proteins | None             | Rh+        | Rh+ or Rh-   |
| +/-      | Rh+       | Rh(D) proteins | None             | Rh+        | Rh+ or Rh-   |
| -/-      | Rh-       | None           | Anti-Rh(D)       | Rh+ or Rh- | Rh-          |

- Rh Sensitization: One interesting medical scenario involves an Rh negative mother who carries an Rh positive baby.
- The baby of an Rh positive father and an Rh negative mother can be +/- or -/-.
- If the baby is +/-, the first pregnancy causes Rh sensitization in the mother, because she is exposed to foreign proteins and builds up antibodies against them.
- Future pregnancies can be increasingly difficult, as the mother's antibodies attack the baby.

If a baby inherits Rh<sup>+</sup> blood from the father and the mother is Rh<sup>-</sup>, problems can develop if the blood cells of mother and baby mix during birth.



# Introduction to Evolution

- Evolution is the **gradual change** of organisms on the earth over long periods, with new forms replacing old ones.
- As evolution has progressed new species are arising, the biodiversity of the planet increasing, larger and more complex organisms replaced the smaller and some species has get extinct.

- Evolution can also be the **change in genetic composition** of a population over successive generations which may be caused by meiosis, hybridization, natural selection or mutation.
- This leads to a sequence of events by which the population diverges from other populations of the same species and may lead to the origin of a new species.

## **Theories about the origin of life on Earth**

- The theory of evolution describes how the various forms of life on earth (including humans) emerged and developed.

- There are five main theories of the origin of life on Earth:
  - special creationism
  - spontaneous generation
  - eternity of life
  - cosmozoan theory
  - biochemical origin

## a) Special creationism

- Special creation theory states that the different forms of life on earth were created by a Supreme Being/ God/ at once with six days.
- Special creation is always linked to religion and mainly focused on spiritual matters that cannot be seen, touched or measured effectively.
- There are two views on the origin of life:

## Types of creationism theory

- Gap creation – discusses a large gap between the formation of the earth and the creation of all the animals and plants. The gap could be billions or millions of year.
- Progressive creation – accepts the Big Bangs as the origin of the universe. It accepts the fossil record of a series of creation for all of the organisms but it does not accept these as part of a continuing process (each is seen as unique creation).
- Evolutionary creationism (Theistic evolution) – This view of evolution maintains that God “invented” evolution and takes some form of an active part in the ongoing process of evolution.
- Intelligent design – a theory states that life developed (formed) due to a combination of natural forces and the intervention of a supernatural being.

## b) Spontaneous generation theory

- Suggests that life can evolve 'spontaneously' from non-living objects. E.g. people believed that rotting meat turned into flies.

## c) Eternity of life

- The theory of eternity of life states that the universe has always existed and that there has always been life in the universe.
- There is no beginning and no end to life on earth and so life is neither created nor generated from non-living matters

## d) Cosmozoan Theory

- States that life on the earth originally came from elsewhere in the universe (possibly from another planet). E.g. Meteorites brought bacterial spores, germs to the earth.
- This theory did not gain any significant support because it lacks evidence and it is strongly linked to the “eternity of life” theory of the origin of life.

## e) Biochemical theory

- It suggests that life on earth originated as a result of a number of biochemical reactions producing organic molecules, which combined (associated) to form cells.
- This theory is also called abiogenesis; states life originates from chemical inanimate (abiotic substances).
- The two scientists (biologists) who developed the theory of abiogenesis (origin of life from chemicals) were:- Aleksander Oparin (1924) and John Haldane (1929). They both suggested:

- The primitive atmosphere of the earth was a reducing atmosphere – no free oxygen (no oxygen gas).
  - primitive atmosphere:  $\text{NH}_3$ ,  $\text{H}_2$ , water vapour ( $\text{H}_2\text{O}$  (g)) and  $\text{CH}_4$
- There was an appropriate supply of energy, such as lightening or ultraviolet light (Uv – rays).
- This would provide the energy for reactions that would synthesize a wide range of organic compounds (amino acids, sugars and fatty acids).

- Oparin suggested that the atmosphere of the primitive earth contained  $\text{NH}_3$ ,  $\text{H}_2$ , water vapour ( $\text{H}_2\text{O (g)}$ ) and  $\text{CH}_4$ . He suggested that at high temperature (above boiling point), these gases could have undergone a series of chemical reactions and might have formed colloidal aggregates or coacervates (collections of droplets that composed of molecules of different types).
- Oparin considered that these coacervates were able to absorb and assimilate organic compounds (amino acids, DNA and others) and leading to the first true cells.

- J. Haldane – proposed that the chemical reactions of these gases were occurred in the primitive sea by solar energy and the sea became a “hot dilute soup” of organic monomers and small polymers.

- In 1953, Stanley Miller tested the biochemical theory. He applied electrical sparks repeatedly through a mixture of gases ( $\text{NH}_3$ , water,  $\text{H}_2$  and  $\text{CH}_4$ ) that were represent the primitive atmosphere of the earth (no oxygen) connected a flask of heated water.
- Miller leaving the equipment for longer periods of time, a larger variety and more complex organic molecules were formed including:

- amino acids - to form proteins
- pentose sugar - to form nucleic acids
- hexose sugar - need for respiration and to form starch and cellulose.
- Hydrogen cyanide (HCN)- starting point for synthesizes of nitrogen containing bases in nucleotides. This experiment gave strong evidence to support the Oparin-Haldane hypothesis.

- **Origin of Autotrophy:** The first life (cell) appeared on earth – about 4 billion years ago and they were:- anaerobes, heterotrophs and prokaryotes.
- They would have fed on organic chemicals (soup) which formed spontaneously in the waters of the earth. The three consecutive lines of evolution of organisms on earth leading to:
  - **Archaeobacteria - are first appeared organisms.** They are prokaryotes including thermophilic (high temp. loving), sulphobacteria, methanobacteria and halophilic (salt loving) bacteria.

- They can survive under harsh (extreme) environment.
- **Eubacteria** – are true (ordinary) bacteria, ordinary bacteria and cyanobacteria (blue – green algae)
- **Prokaryotes** – evolved into protista, fungi, plants, animals (nearly all are aerobes).

- Later (3.5 billion years ago) – the first **autotrophs (photosynthetic organisms)** like **cyanobacteria (blue-green algae)** came in existence. With the evolution of chlorophyll molecules, oxygen ( $O_2$ ) was released as a by-product of photosynthesis and this changes the earth's atmosphere from the reducing to an atmosphere containing oxygen.
- The fossil record shows that cyanobacteria had been producing oxygen by photosynthesis from about 305 million years ago but the levels of oxygen in atmosphere did not rise for almost 1 billion years ago. Because oxygen was absorbed by the vast amount iron in the earth it rusted.

## Theories of Evolution

- There have been many theories of evolution that have explained:- how does evolution happen? And what drives the population to become a new species?

## A. Lamarck Theory of evolution

- In the 19th century (1809), Lamarck published a paper entitled Philosophic “Zoologique” in which he described the two-part mechanism by which change was gradually introduced into the species and passed down through the generations. This theory is also called “theory of transformation” or **Lamarckism**. The two parts of Lamarck theory are:
  - Use and disuse
  - Inheritance acquired traits

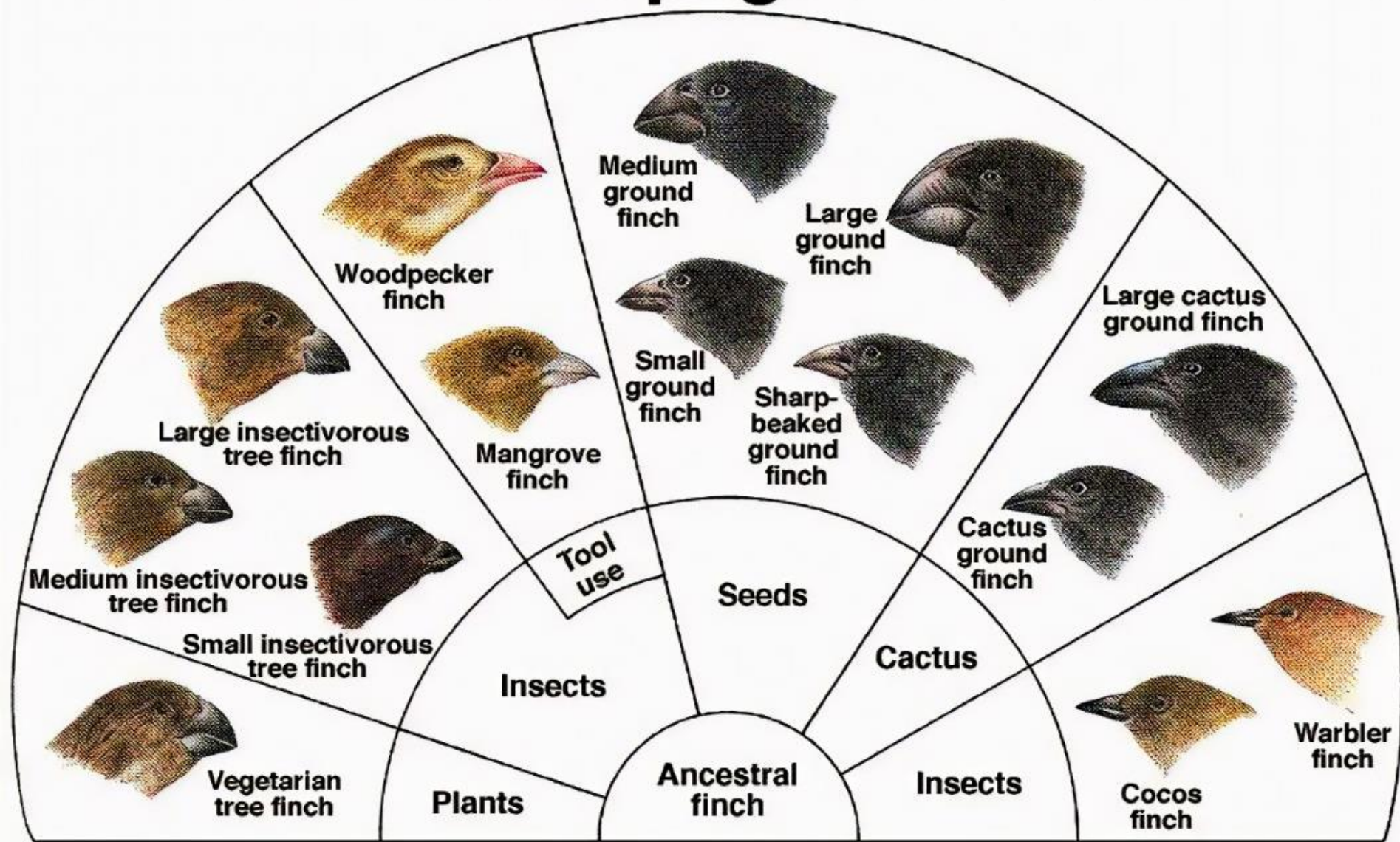
- **Use and disuse** – Lamarck suggested that a structure or process in organism that can be used continuously will become enlarged or more developed but any structure that is not. Example,
- According to Lamarck, giraffe had short neck but they stretched their neck to reach high branches, developed an elongated neck - **use theory**.
- The wings of penguins would have become smaller than those of other birds because penguins do not use their wings to fly - **disuse theory**.

- **Inheritance of Acquired traits** – Lamarck believed that traits changed (acquired during an organism's lifetime) could be passed on to its offsprings. Example: - Giraffes that had acquired long necks would have offspring with long necks.
- Note: - **Nowadays**, Lamarck's theories are not accepted because the environmental changes that were believed by Lamarck have brought about the changes in the phenotypes (Physical appearance) of the organisms have no effect on their gametes and hence their heredity.

## B. Charles Darwin and Natural Selection

- In 1858, both Charles Darwin and Alfred Wallace jointly published a scientific paper that proposed **species were modified by natural selection**.
- Darwin visited five of the Galapagos Islands, made drawings, and collected species. In particular, Darwin studied the finches found on the different islands and noted there were many similarities between them but have some obvious differences.

# on the Galapagos Islands



- Darwin concluded that an “ancestral finch” had colonized the Islands from mainland and been able to adapt to the different conditions on the islands and evolve into different species. E.g. He suggested that some finches had evolved into insect eaters (pointed peak), other in to seedeaters (crushing peak).
- Darwin summarized his observations in two main ideas:
  - all species tend to produce more offsprings than can possibly survive (Fecundity)
  - there is a variation among the offsprings.

- From these observation Darwin deduced (concluded) that:
  - There will be a “struggle for existence” between members of a species because they are over – reproduced and resources are limited.
  - Some members of a species will be better adapted than others to the environment because there is a variation in the offspring.
- Darwin proposed: - Those members of a species, which are best adapted to their environment, will survive and reproduce in greater number than other less adapted (died out).

## C. Neo – Darwinism Theory

- Charles Darwin knew very little about genetics and did not propose how variations in the population was passed to the next generation.
- Nowadays, **genes** and gene action are **the driving force of evolution** in the theory of Natural selection.
- A Gene pool is all the alleles in the **population**. **It might be evolve a population into a new species**. Suppose an allele determines a feature that gives an organism an advantage in its environment. The following will happen

- Those individuals with the advantageous allele of a gene will survive to reproduce in greater number than other types
- Advantageous allele pass to their offsprings in greater numbers than other genes (alleles).
- The frequency of the advantageous allele will be higher in the next generation of a population.

- **Mutations** are important in introducing variation into population. Any mutation could produce an allele which:
  - increase in frequency if they are beneficial in their effect, may increase slowly, stable or decrease if they are neutral and decrease and could disappear if they are harmful (disadvantages) in their effects.
- Neo-Darwinism is a modification of Darwin's original theory that takes into account:- genetics and ethology (behavioural patterns can also be advantageous or not). E.g. Young geese "imprint" upon the first moving object after they are hatched.

Thanks!