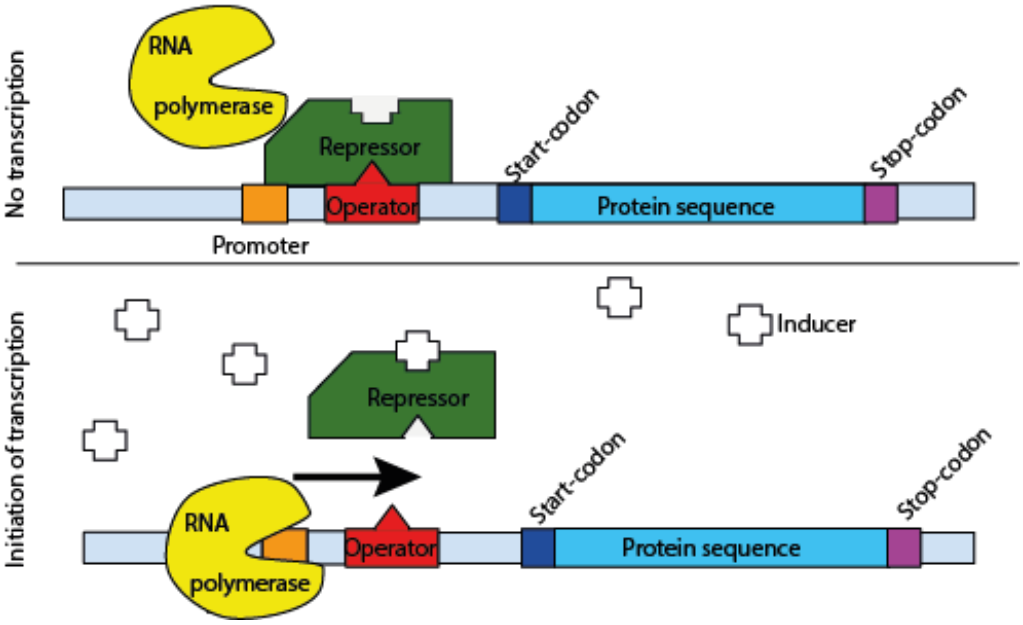
## Understandings:

**1. Explain how gene expression is regulated.**

- What does it even mean to ”regulate a gene expression”? Well, think about it. All cells in our body have the same DNA. However, do we need to produce hormones in skin cells? Do we need to produce haemoglobins from our retina cells? NO! The cells make different proteins in accordance to their function. In other words, the gene expressions are regulated.

The next question is how this works. There are many ways.




There are repressors (protein) that can regulate in presence of a particular substance. For instance in E.Coli (bacteria in our intestine) when there is lactose, its repressor for lactase gene deactivates and enables RNA polymerase to transcribe lactases.

There are silencers, which are proteins that can inhibit an expression.

There are enhancers, which are also proteins but that exhibits (increases the rate) of gene expression.

There are promoters, which is a part in the DNA sequence that works together with the repressor, silencers and enhancers.

**2. Explain how environment impacts on gene expression.**

- We know for sure that the environment has the ability to cause an effect in organism's gene expression, such as the lactase regulation and skin pigmentation.

Two very similar examples are Siamese cats and Himalayan rabbits.

Depending on the temperature the pigment production will be different. In the hotter body areas, we have "C" gene codes to produce tyrosinase which in turn makes pigments.

However, on cooler areas, such as nose, feet and ears, a mutant gene "$c^s$" will be produced and make it black.


**3. Explain how nucleosomes help to regulate transcription.**

- As we know, eukaryotic cells have DNA wrapped in histones. Small changes in the histone will determine whether a gene should be expressed or not.

For instance, methyl groups, phosphate groups and acetyl groups may be added/removed.

In essence, the adding/removing changes the charge into a neutral charge. Since DNA are negatively charged, histones will not bind as much when it turns is neutral. This leads to that DNA loses its "condensed" structure that would have inhibited DNA. Now transcription can happen more easily because unwrapping is not needed.

**4. State the direction of transcription.**

- Just like DNA polymerase, the RNA polymerase works in 5' to 3' direction.

Also know that nucleotides are not attached as nucleotides. They are attached as free nucleoside triphosphates. As they are bonded, they lose two phosphates (not three) and the rest is the same as DNA replication.

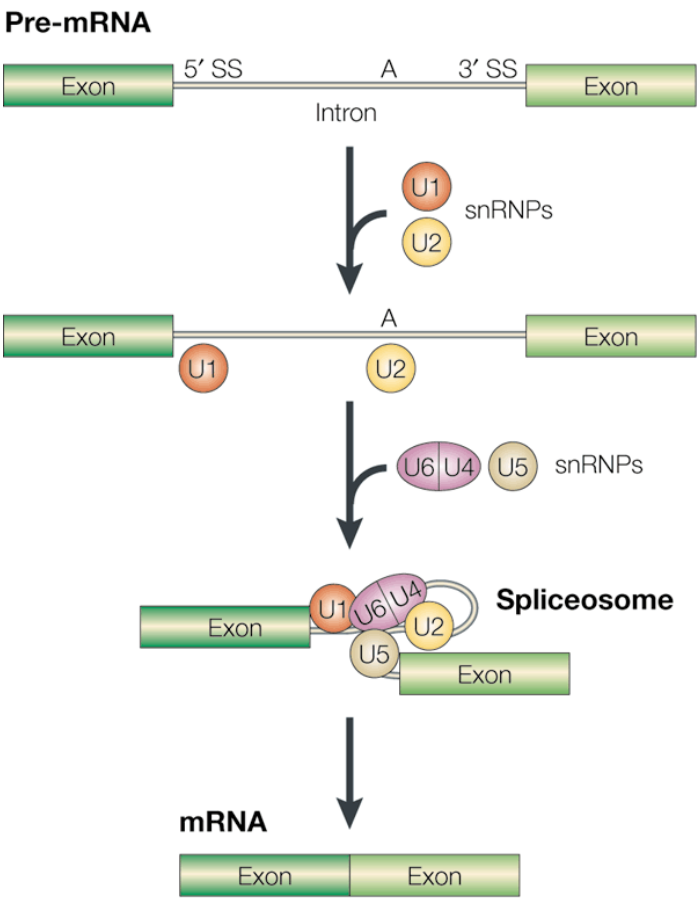
**5. Explain how eukaryotes modify their mRNA after transcription.**

- So what do we have after transcription? Yes, we have an mRNA molecule. From this stage, what prokaryotes do and what eukaryotes do is very different. Here is the reason why.

Since prokaryotes do not have a nuclear membrane, the transcription and translation happens in the same place and can therefore be seen as "one process coupled together". So once an mRNA, it is the same mRNA that will code for proteins because prokaryotes do not have introns.

What about eukaryotes then? After the mRNA has been produced, it is still in the nucleus. But the problem is, the mRNA contains bunch of useless introns!!! So basically, we remove them before sending it out to ribosomes. This process of removing introns and joining the remaining exons is called "splicing". Splicing by definition means "joining", which in this case means joining the exons!

Here is an illustration of what happens.

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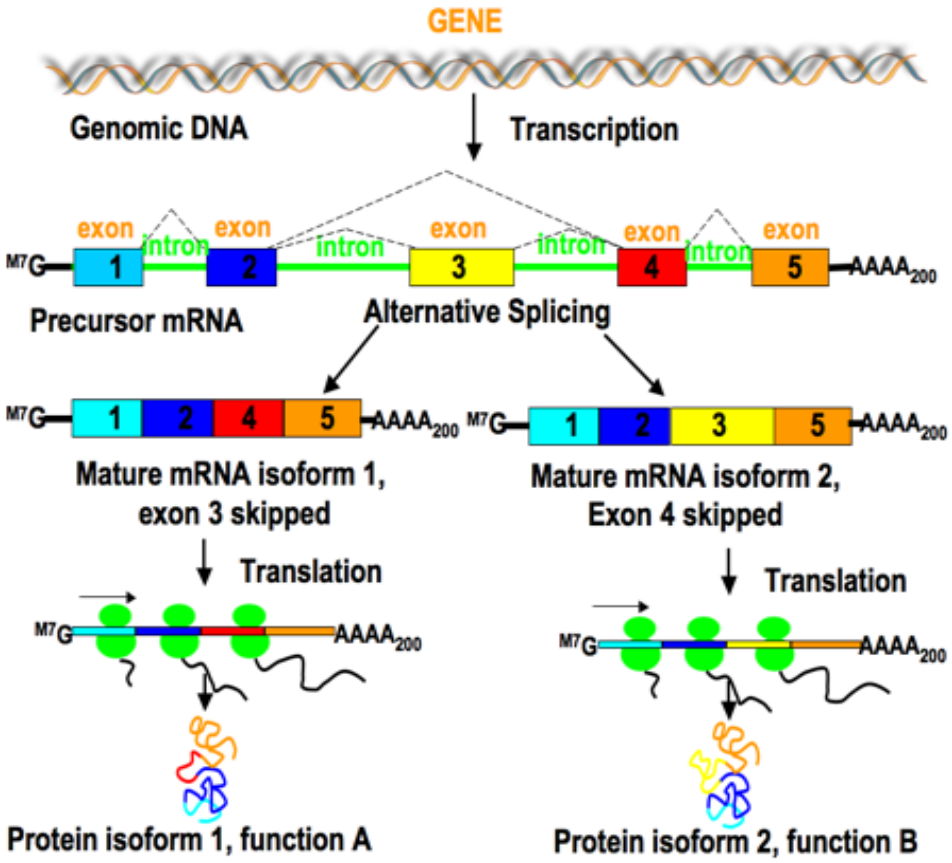
We can see that there is this pre-mRNA in the beginning which is the immediate product after transcription.

Some enzymes take away the intron; join the exons, and they form a mature mRNA!

**6. Explain what alternative mRNA splicing is.**

- To add what has just been said about mRNA splicing, splicing does not only involve taking away an intron. Even exons can be excluded or included.




We can have different combinations of exons to produce what we call different protein isoforms.

We can see from the left that exon 3 is excluded in first one and exon 4 is skipped in the second one.

A possible evolutionary reason is that the alternative splicing gives rise to exponentially more varieties of proteins. In addition, it seems more effective to have the ability to alternatively splice from a set of mRNA rather than having the exact sequence of mRNA that is inflexible. This would mean more genetic material. More genetic material would take more space, and we know that cells have a certain surface area to volume ratio they have to follow!

## Applications and skills:

**1. Explain the promoter as a non-coding DNA with a function.**
- We know that tRNA and mRNA are non-coding DNA with a function during translation.

Another example is the promoter. This is a location near a gene that enables RNA polymerase to bind in order to transcribe.

**2. Explain what epigenetics is.**
- Epigenetics is the study of gene expression, since about 1970s. The fundamental question that drives this study is "Am I who I am because of my inherited DNA, or my experiences?" or Nurture vs Nature.

We certainly know that environment can cause chemical changes in our gene expression through methylation, acetylation, and phosphorylation and probably more. We call those changes epigenetic tags.

Scientists have found out that environmental causes actually might be hereditary. This is why a family that had cancer have a high chance of passing on the cancer to next generation.

What people have done to prove this is to study twins raised in different environments. Twins have identical DNA, but changes in environment made changes in their gene expression or epigenetic tags. Then, their children had the similar traits as their parents! Scary…

**Extra notes**
- What is methylation? Methylation is "addition of methyl group $-CH_3$". The base cytosine can be methylated to form methylcytosine. Why do we want to do it? Well, this inhibits the transcription and therefore prevents further expression of genes. Environment can affect methylation and the patterns of methylation can also be passed on.

## TOK:

**1. The nature versus nurture debate concerning the relative importance of an individual's innate qualities versus those acquired through experiences is still under discussion. Is it important for science to attempt to answer this question?**