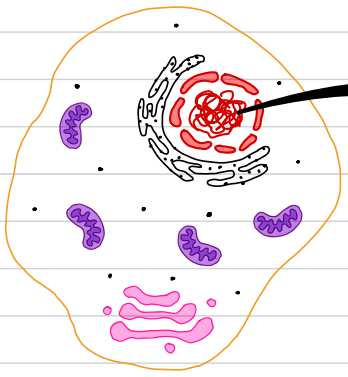
Gene Expression

Learning Outcomes

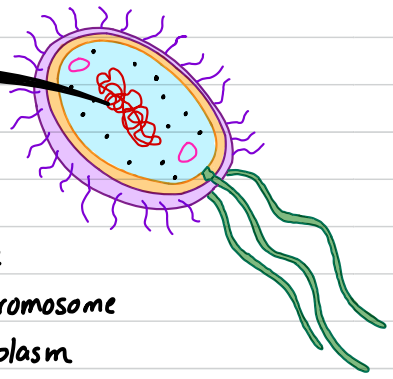
- *17.1.1* – **State** that chromosomes are made of DNA, which contains genetic information in the form of genes
- *17.1.2* – **Define** a gene as a length of DNA that codes for a protein
- *17.1.3* – **Define** an allele as an alternative form of a gene
- *17.1.5* – **State** that the sequence of bases in a gene determines the sequence of amino acids used to make a specific protein (knowledge of the details of nucleotide structure is not required)
- *17.1.6* – **Explain** that different sequences of amino acids give different shapes to protein molecules
- *17.1.7* – **Explain** that DNA controls cell function by controlling the production of proteins, including enzymes, membrane carriers and receptors for neurotransmitters
- *17.1.8* – **Explain** how a protein is made, limited to:
  - the gene coding for the protein remains in the nucleus
  - messenger RNA (mRNA) is a copy of a gene
  - mRNA molecules are made in the nucleus and move to the cytoplasm the mRNA passes through ribosomes
  - the ribosome assembles amino acids into protein molecules
  - the specific sequence of amino acids is determined by the sequence of bases in the mRNA
- *17.1.9* – **Explain** that most body cells in an organism contain the same genes, but many genes in a particular cell are not expressed because the cell only makes the specific proteins it needs
- *17.1.10* – **Describe** a haploid nucleus as a nucleus containing a single set of chromosomes
- *17.1.11* – **Describe** a diploid nucleus as a nucleus containing two sets of chromosomes
- *17.1.12* – **State** that in a diploid cell, there is a pair of each type of chromosome and in a human diploid cell there are 23 pairs

Chromosomes and the Genetic Code

genetic information found within organisms are arranged as chromosomes



↳ in eukaryotes there are many linear chromosomes in the nucleus



↳ in bacteria there is one circular chromosome in the cytoplasm

a **chromosome** is a super coiled DNA molecule which contains genetic information in the form of genes

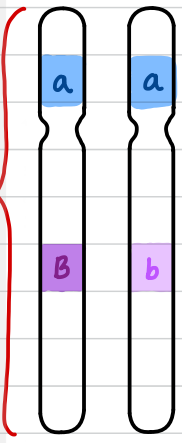
a **gene** is a length of DNA that codes for a protein
- ↳ genes are heritable : passed from parent to offspring
- ↳ genes control specific characteristics of individuals

In eukaryotes, the number of chromosomes varies significantly between different species
ex: mosquitoes = 6, wheat = 42, horses = 64 and humans = 46

↳ chromosomes are often organized in pairs, called **homologous pairs**

↳ homologous chromosomes have the same length, same genes at the same location

BUT they are often not identical as each pair may have a different form of a gene: **allele**



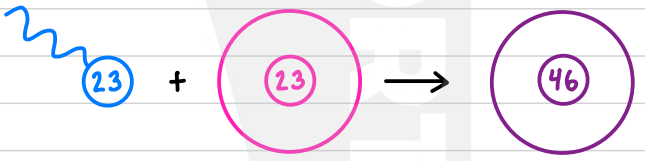
gene for face freckles
↳ both alleles for no freckles

gene for earlobe shape
↳ allele for free earlobes
↳ allele for attached earlobes

The majority of your body's (somatic) cells have homologous pairs (2 sets of each chromosome) in their nucleus : **diploid**
↳ 'di' means 2

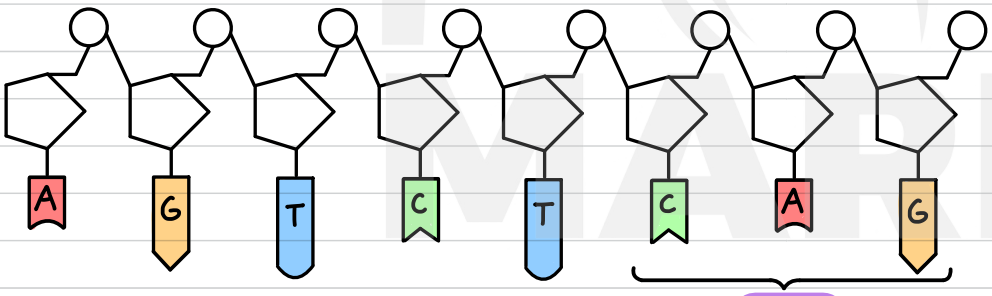
Your sex cells (gametes) have only one of each homologous pair (1 set of each chromosome) in their nucleus · **haploid**
↳ 'haplous' means single

Why? During fertilisation, the haploid nucleus of sperm fuses with the haploid nucleus of ovum to produce a diploid zygote



zygote has 2 copies of each chromosome (2×23=46)

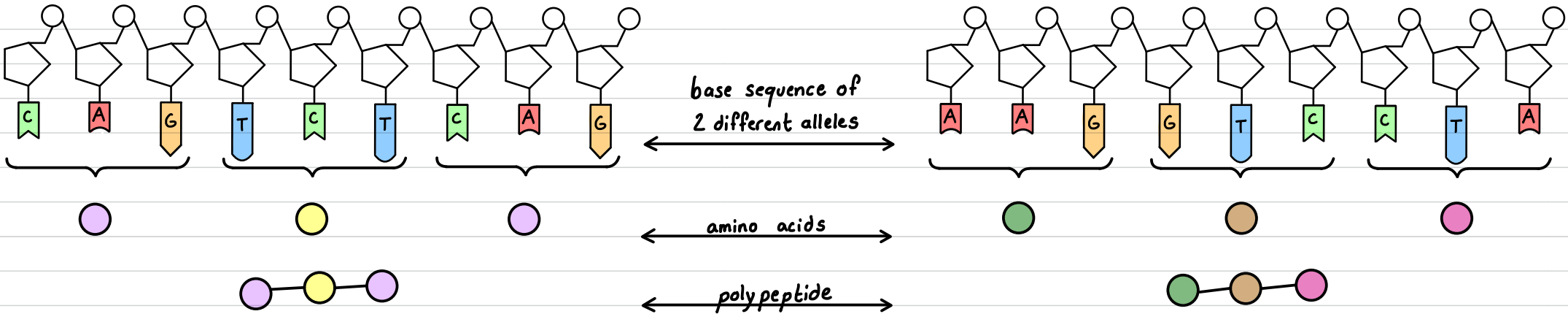
genetic code : the base sequence of nucleotides in DNA or RNA
↳ the order of the code determines which amino acids are formed in what order



genes and codons don't make proteins, rather they provide instructions on how to make them

like how a cook book doesn't make meals but instructions on how to prepare them

codon: 3 nucleotide base sequence that codes for a particular amino acid
↳ 20 different amino acids, each with different codons that code for them



different alleles have a different base sequence → different sequence codes for different amino acids
different proteins have different shapes and thus functions ← different amino acid sequence forms different proteins

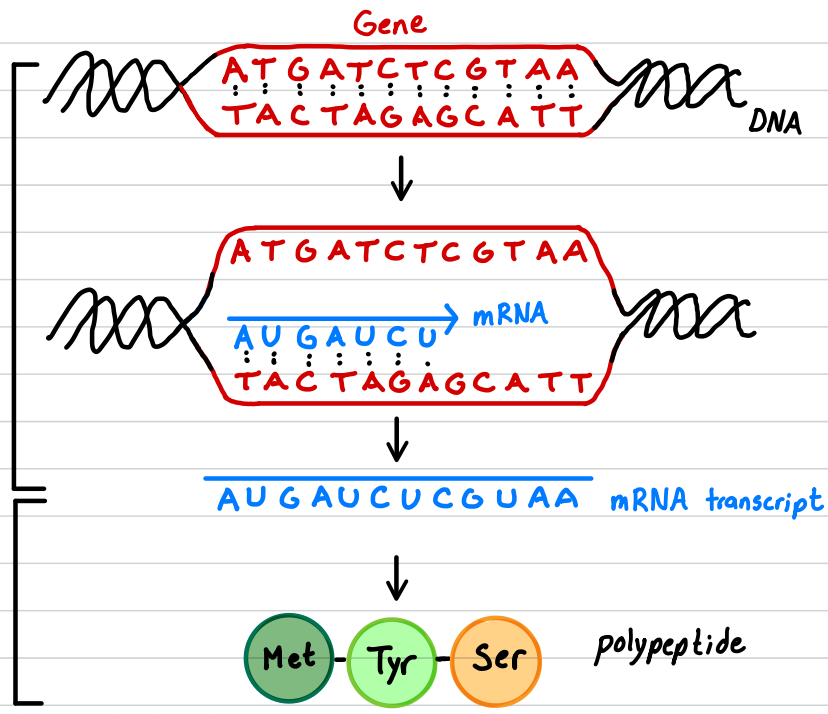
Protein Synthesis

Protein synthesis or gene expression is the process by which instructions in DNA (genes) are converted into a functional product - a protein

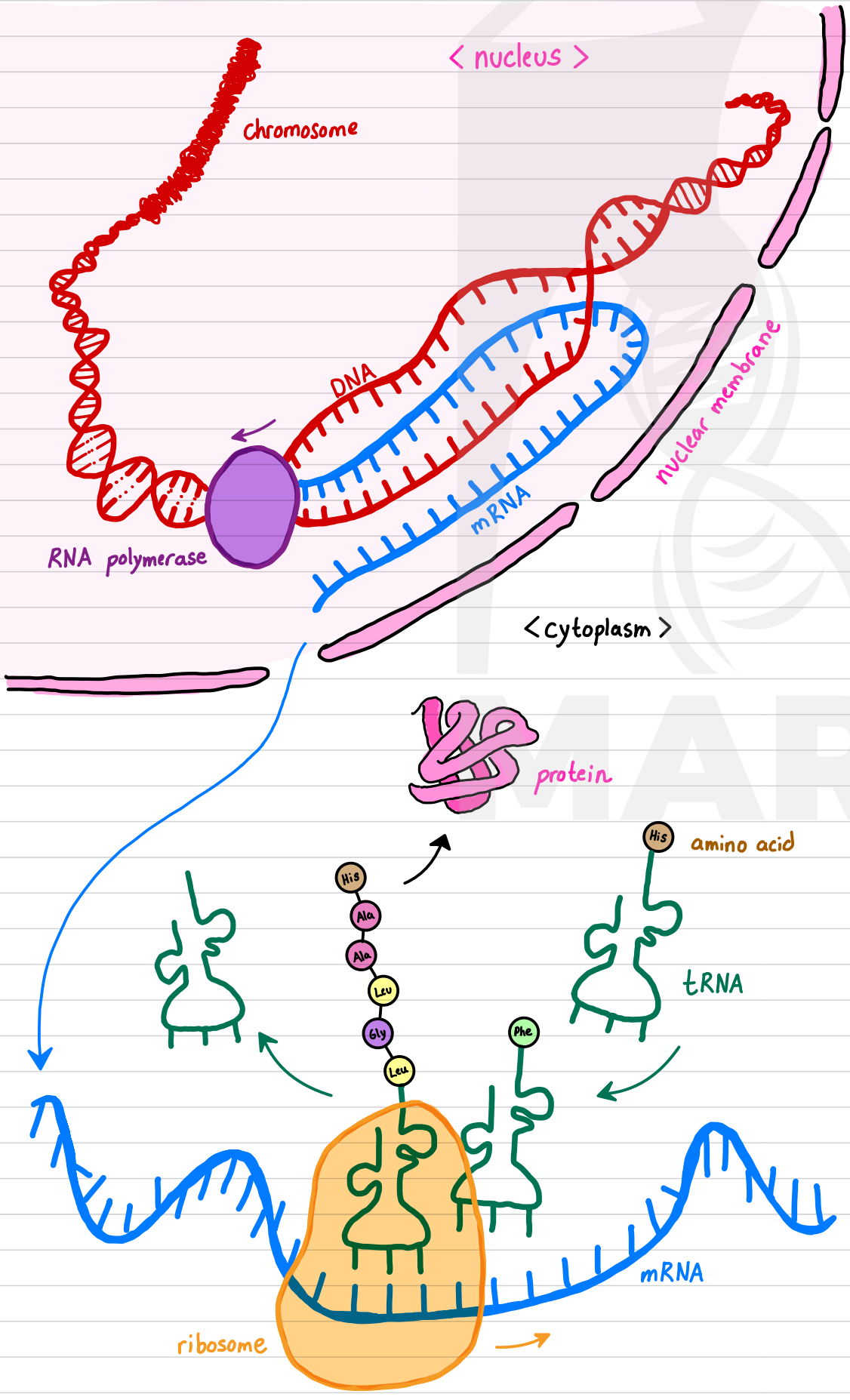
↳ The process comprises of 2 steps:

① **Transcription** : DNA is unwound and the gene (template) is copied into a complementary mRNA (messenger RNA) single-stranded transcript

② **Translation**: genetic information in mRNA is translated into a sequence of amino acids in a polypeptide chain, i.e. protein



Central Dogma of Molecular Biology : genetic information flows in one direction - from DNA → RNA → proteins



1 Transcription

DNA gene → mRNA transcript

(a) In the nucleus (in eukaryotes) DNA double helix is unwound by the enzyme RNA polymerase

(b) RNA polymerase moves and reads the gene on DNA

(c) using one strand as a template, RNA polymerase synthesizes a complementary mRNA copy

DNA	A	A	T	C	C	G	A	T	G
mRNA	U	U	A	G	G	C	U	A	C

* RNA does not use the base T but instead Uracil (U) which is complementary to A and has ribose insead of deoxyribose

(d) once gene is copied, DNA rewinds and mRNA leaves nucleus via nuclear pore into the cytoplasm

2 Translation

mRNA transcript → protein

(a) mRNA binds to a ribosome

(b) ribosome reads mRNA, one codon at a time

(c) tRNA (transfer RNA) brings amino acid to the ribosome that corresponds to correct codon

(d) amino acids form peptide bonds, combining together into a polypeptide

mRNA codons	U	U	A	G	G	C	U	A	C
amino acids	Leu			Gly			Tyr		

→ Leu–Gly–Tyr

(e) polypeptide folds into protein

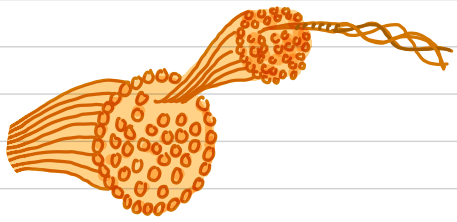
Gene Expression

Protein shape → function

The gene sequence determines the number and order of amino acids which in turn determine its structure and function:

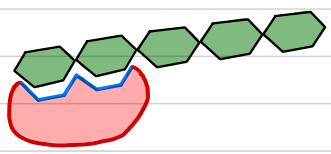
↳ Some proteins are fibrous, these are typically structural

ex: collagen



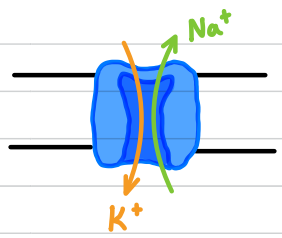
↳ enzymes are globular proteins with specific shapes i.e. their active site

ex: amylase



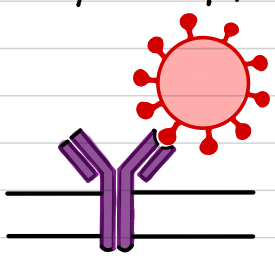
↳ membrane carriers have specific shapes which allow the transport of substances

ex: Na^+/K^+ pump

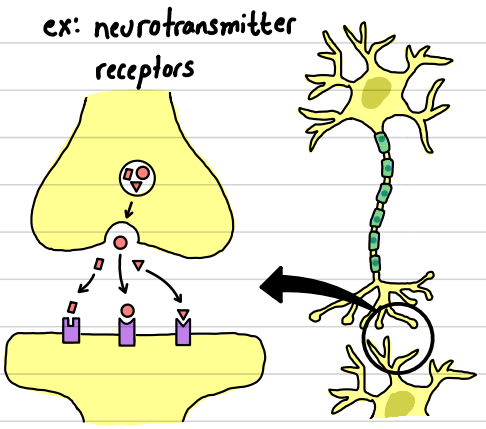


↳ receptors bind onto specific substances to initiate a response

ex: receptors on lymphocytes



ex: neurotransmitter receptors



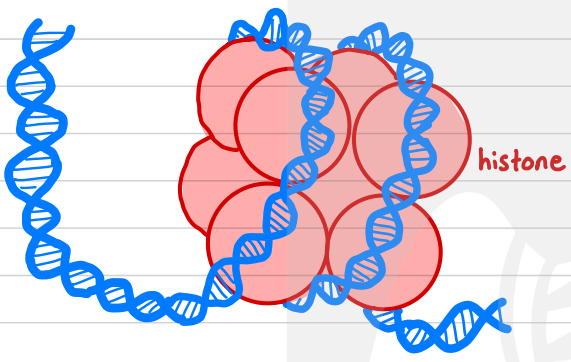
In eukaryotes, not all cells perform the same functions, and therefore do not have the same requirements for proteins

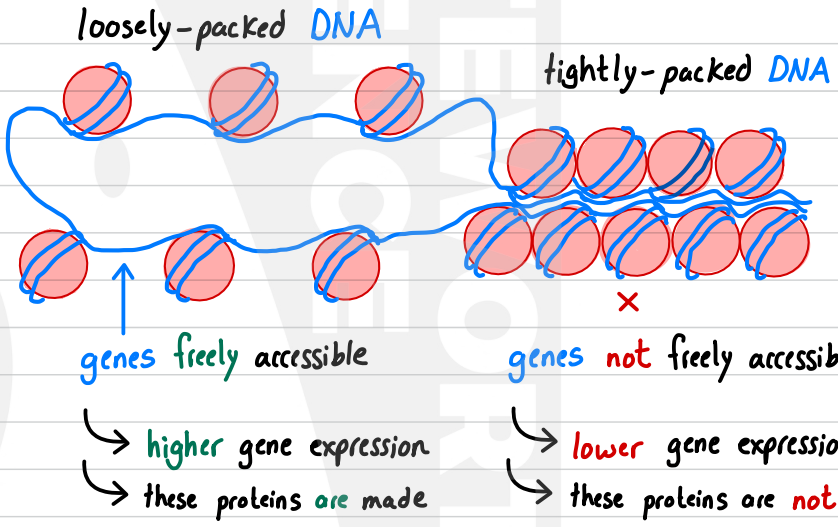
why like society, it is more efficient to specialize and have certain members perform specific functions → cell differentiation

how when cells specialize, they express some of their genes (make some proteins) and no longer express other genes (don't make some proteins)

DNA is wrapped around proteins called histones

↳ histones can control how packed DNA is around them





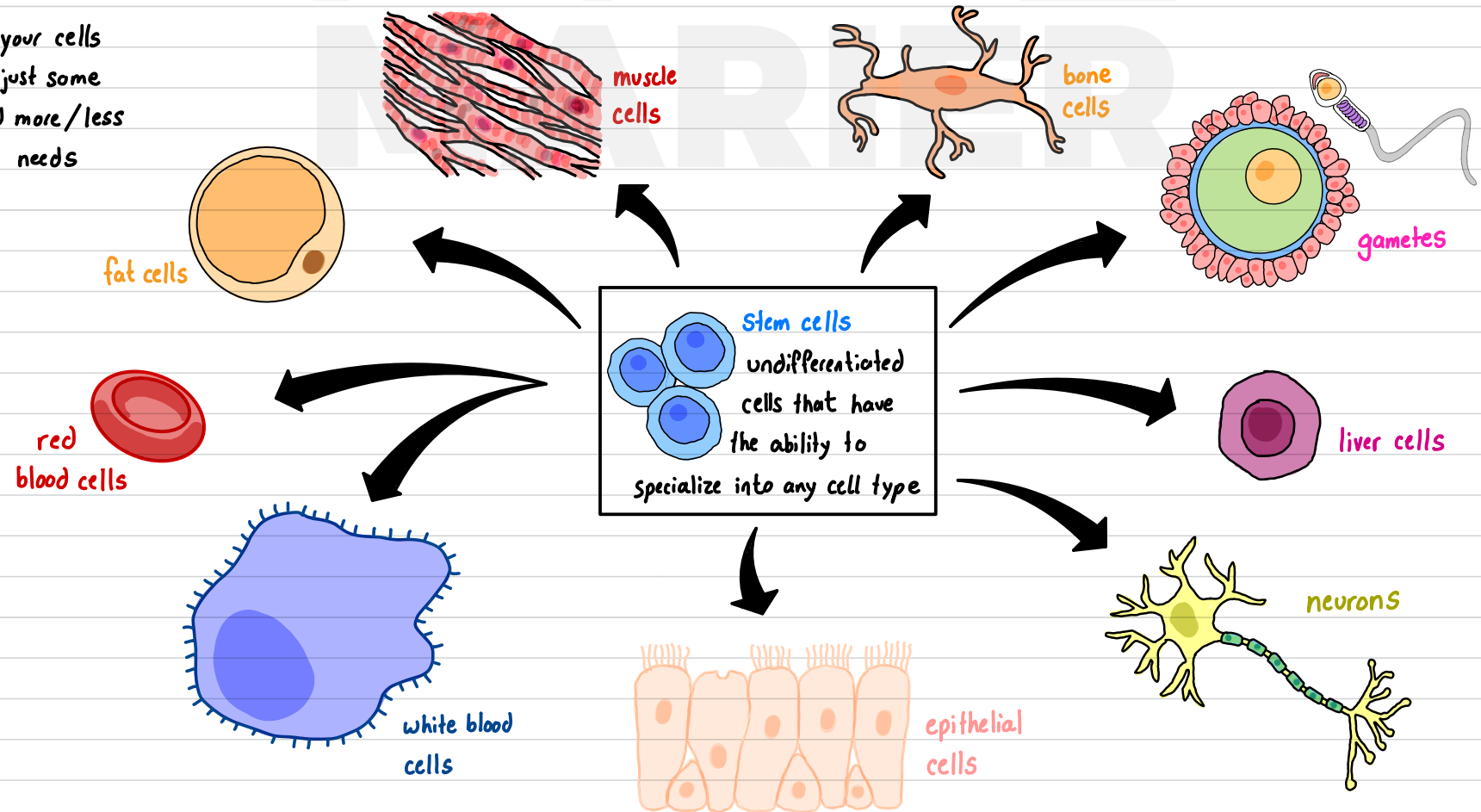
↳ higher gene expression
↳ these proteins are made

↳ lower gene expression
↳ these proteins are not made

Cell differentiation:

Nearly all of your body cells contain the same genes*, but they look and act different due to differentiation (specialization)
When stem cells differentiate, gene expression changes: some genes 'turned on' and others 'turned off' based on the cell's function and protein requirement

* DNA in all your cells is identical, just some genes are used more/less based on its needs



Assessment Tasks

Answer the following questions:

(1) Humans typically have 23 pairs of chromosomes in their body cells. In some cases, when a sperm or ovum is produced, they have 22 or 24 chromosomes, resulting from a process called non-disjunction.
Research two different disorders: one where the human has 47 chromosomes and one where the human has 45.
For each, provide the name and a description of the effects this has on the individual

(2) Using the following DNA template strand below, deduce the mRNA transcript that would be produced in transcription.

$\overline{TACAATCGCTTTGGTAAAACT}$

(3) Using the following mRNA codon table, deduce the amino acid sequence that would be translated from the transcript in (2)

Second letter

First letter	U	C	A	G	Third letter
U	UUU Phe UUC Phe UUA Leu UUG Leu	UCU Ser UCC Ser UCA Ser UCG Ser	UAU Tyr UAC Tyr **UAA Stop** **UAG Stop**	UGU Cys UGC Cys **UGA Stop** UGG Trp	U C A G
C	CUU Leu CUC Leu CUA Leu CUG Leu	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**	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

(4) Contrast the structures of DNA and RNA

(5) A stem cell and lymphocyte are extracted from a person. How would these cells be similar and how would they be different?

(6) Stem cells have enormous potential in medical applications. Research 2 medical conditions. For each:
a) Describe the medical condition and explain why currently there isn't a cure
b) Explain how stem cells could potentially be used to treat this condition

MARIER