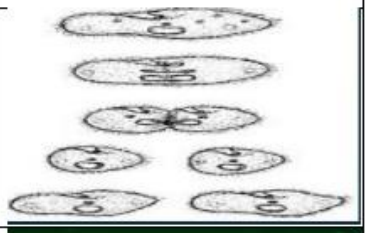
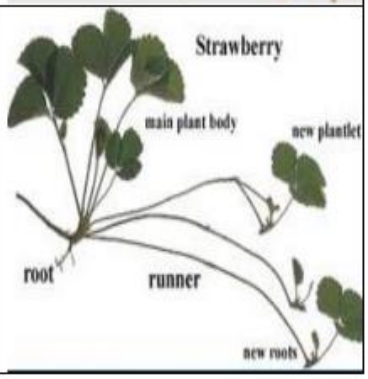
# The Purpose of Life: Reproduction?

## Sexual vs Asexual

| | Sexual | Asexual |
|---|---|---|
| **Parent** | Two unsexual parents: female and male or hermaphrodites | **One parent** |
| **Gamete (sex cells)** | Specialized reproductive cells: pollen / sperms (male gamete) and ovum or egg (female gamete) | **Specialized reproductive cells are not formed** |
| **Meiosis** | Occur at some stages to produce haploid cell or gametes. | **None** |
| **Progeny (offspring)** | Not identical to parents | **Genetically identical to its parents except for those undergo mutation** |
| **Occurrence** | In many animals and plants | **Plants, prokaryotes and mosses / liverworts.** |
| **Advantage** | Genetic variability | **Faster growth and necessity for the existence for two parents does not arise** |

# Advantages and Disadvantages

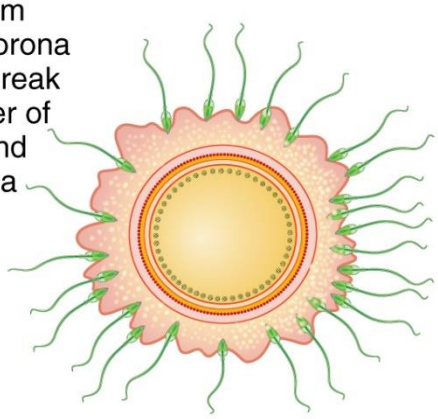
| Sexual Reproduction Advantages | Sexual Reproduction Disadvantages |
|---|---|
| • Can adapt easier to environmental changes<br>• Increases genetic variation within a species<br>• Allows for diversity and evolution of a species | • Takes longer to reproduce offspring<br>• More things can go wrong (Mutations)<br>• Must locate a mate to reproduce |
| **Asexual Reproduction Advantages** | **Asexual Reproduction Disadvantages** |
| • Only need one parent to reproduce<br>• Requires less energy to reproduce<br>• Can reproduce quickly | • Genetically similar and less able to survive environmental changes<br>• Can be easily wiped out by diseases<br>• Can result in overcrowding of a habitat |

| **Type of Asexual Reproduction** | **Description** | **Organisms That Use It** | **Image** |
|---|---|---|---|
| Binary Fission | Cell Division through mitosis | Bacteria, Amoeba |  |
| Budding | Bud grows from the body of parent organism through mitosis | Hydra, Cactus, Yeast |  |
| Fragmentation/Regeneration | Offspring grows from a piece of its parent through mitosis | Starfish, Axolotl, Plant Cuttings |  |
| Vegetative Propagation | (Plants) uniform offspring grow from runners that take root in the ground and reproduce through mitosis | Strawberries, Potatoes |  |

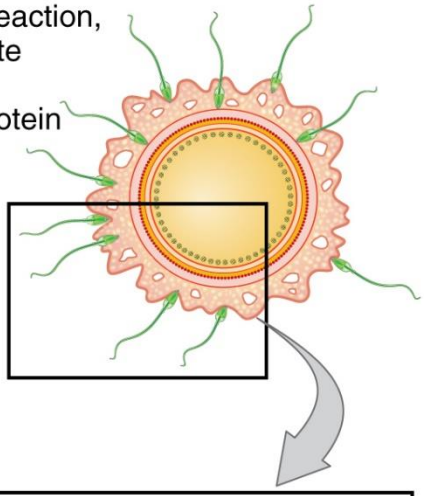
- **Fertilization is the joining male and female gametes (ova and sperm) to produce a zygote.**
- **Sperm need to swim, using their flagella, to the site of conception, which usually occurs in the fallopian.**
- **There is approximately 200+ million sperm in every ejaculate but only a few thousand survive to each the fallopian tube.**
- **Millions are killed off by the acidity of the vagina (pH 3.8)**
- **They can survive for 3-5 days in the uterine cavity, which is why pregnancy is possible for a few days before and after ovulation (release the egg).**

# Fertilization

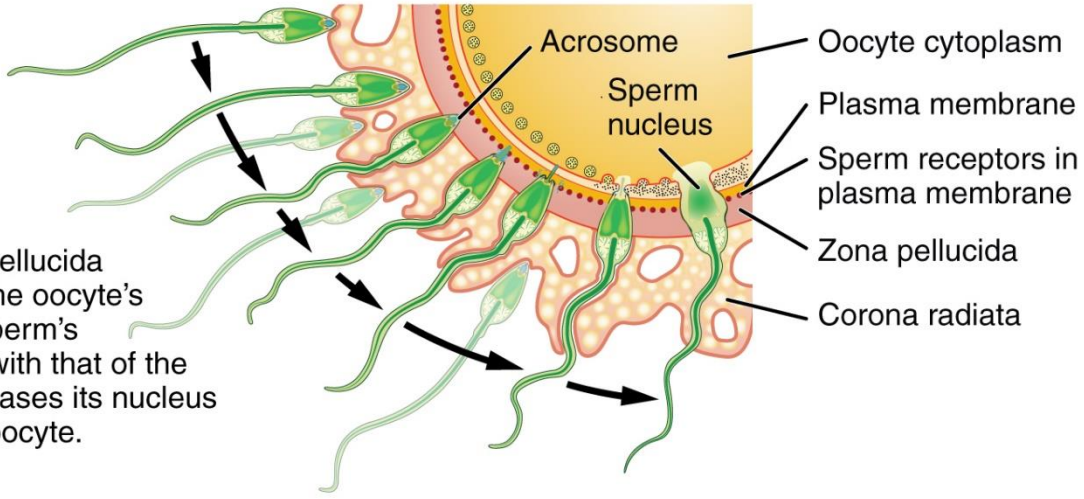
① Hundreds of sperm attracted to the corona radiata begin to break through the barrier of granulosa cells and approach the zona pellucida.



② Contact with the zona pellucida triggers the acrosome reaction, causing sperm to secrete digestive enzymes that break down the glycoprotein membrane of the zona pellucida and help to expose the oocyte's plasma membrane.



③ A single sperm succeeds in burrowing through the corona radiata and zona pellucida and making contact with the oocyte's plasma membrane. The sperm's plasma membrane fuses with that of the oocyte and the sperm releases its nucleus into the cytoplasm of the oocyte.



## Features of Implantation

- **A blastocyst is the stage of development that implants in the lining of the uterus and starts producing its own hormones.**
- **The inner cell mass becomes the developing fetus, while the trophoblast becomes the placenta that helps to nourish the developing embryo.**

## Conception to Implantation

- **The trophoblast also acts to release enzymes that breakdown the uterine lining so that it can embed itself fully in the uterine wall.**
- **HCG is released by the blastocyst to maintain the corpus luteum so that estrogen and progesterone are still released.**
- **At the end of the first trimester the placenta will take over this hormonal control.**

# Hormones involved in the maintenance of pregnancy and birth

- **HCG – (human chorionic gonadotropin) increases rapidly in the 1$^{st}$ trimester, then decreased during 2$^{nd}$ trimester.**
- **HCG remains at a low level during the 3$^{rd}$ trimester.**
- **Estrogen & progesterone both increase steadily in the 1$^{st}$ and 2$^{nd}$ trimester & more rapidly during the third trimester.**
- **Progesterone decreases slightly prior to birth.**

## Hormones involved in birth

- **It is still not known what triggers birth; however the hormone oxytocin prepares the uterus for birth and stimulates its rhythmic contractions during labor.**

- **Synthetic oxytocin is an effective in starting and maintaining uterine contractions as endogenous oxytocin – this is a positive feedback mechanism.**
- **Until birth occurs, the cervix will continue to have pressure from the baby's head.**
- **This pressure triggers oxytocin to be released, which in turn causes contractions that push the baby down the birth canal.**

## The Cell Cycle

- **Nearly all somatic (body) cells undergo cell division, however, the primary role of cells is functional – they have a job to do.**
- **The cell cycle is a sequence of phases that most cells undergo constantly.**
- **The two main phases of the cell cycle are:**

GROWTH →

1) **Interphase: the majority of the cell cycle is spent in this phase where cells are growing ($G_1$), replicating their DNA (S), and performing their function (synthesising proteins,. Etc.) ($G_2$).**

DIVISION →

2) **M-phase: this is where cell division (mitosis) occurs.**

**IMPORTANT !!!: The DNA is mainly unwound during the cell cycle and only forms chromosomes during mitosis.**

### TERM 2

#### MODULE 6

## Inheritance Patterns in a Population

**Biology terms:**

- **Population: a group of individuals of the same species that routinely interbreed (smallest unit in which evolution occurs).**

- **Species:** a group of individual organisms that are capable of interbreeding to produce fertile offspring in nature.
- **Adaptation:** a genetic trait that gives an advantage over another organism
- **Acclimation:** things that an organism can do that it survives in its environment.
- **Mutation:** mutations are changes in the DNA sequence and provide a source for variations.
- **Migration:** immigration (entering a population) will add new alleles to the gene pool and emigration (leaving a population) will remove alleles from the gene pool.

**Cause of evolution:**

- Environmental factors
- Mutations
- Genetic Recombination
- Random pairing of gametes

### Hardy-Weinberg assumptions

- No mutations (no change)
- No migration (no moving out)
- Large population
- Random mating
- No selection occurs

### Hardy-Weinberg Equilibrium

**A population's allele and genotype frequencies are constant, unless there is some type of evolutionary force acting upon them.**

# Genetic Change

# MUTATION

**Definition:** **A change in the arrangement of bases in an individual gene or in the structure of the chromosome (which changes the arrangement of genes).**

## Frequency and Repairs of Mutations

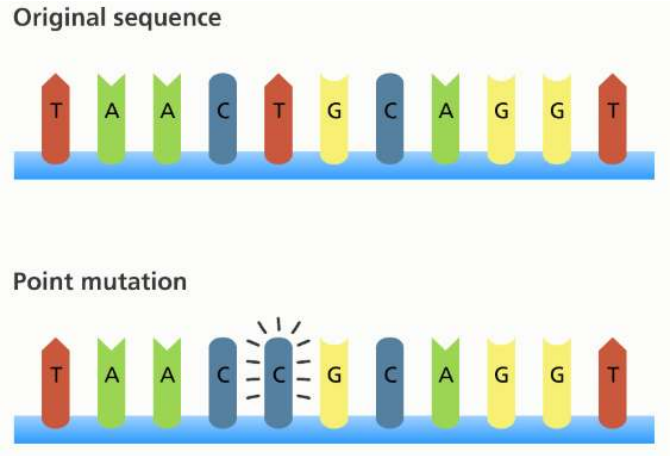
**Mutations can occur in gametes and somatic cells.**

**Faulty DNA can be repaired by specific enzymes.**

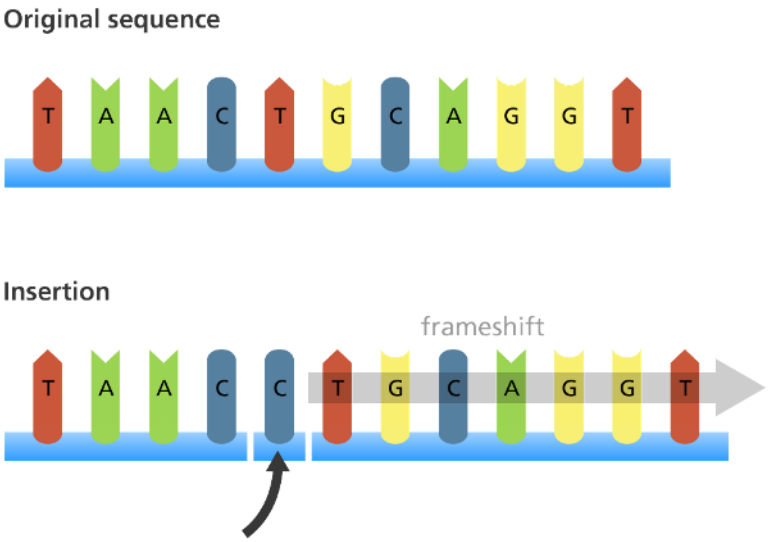
**Unrepaired mutations will affect the new proteins being synthesized (these may be positive or negative effects).**

## Point Mutations Are Caused Because:

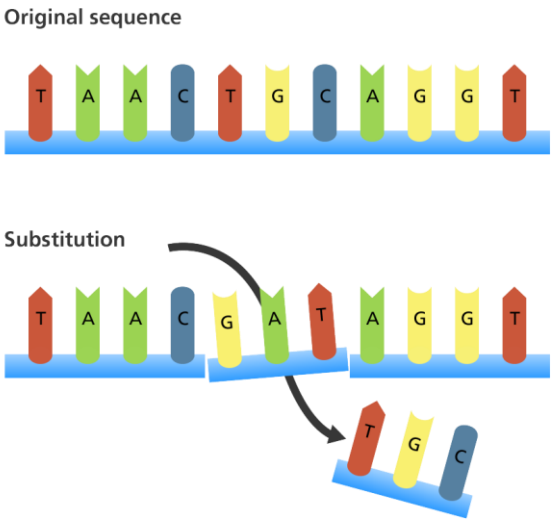
- **Changes in an individual gene, due to miscopying of one or more nucleotides.**




- **Deletion or Insertion of a nucleotide results in a frameshift.**




- **Substitution mutations result in a change of one base, this may cause a different amino acid to be coded for.**



- **Chromosomal mutations:**
  - **Gene deletion: deletion of one or more gene in a chromosome.**
  - **Gene duplication: replication of one or more genes in a chromosome.**
  - **Inversion (2 or more genes swapped in a chromosome)**
  - **Translocation**

## The effect of mutations

- **Production of new/superior protein**
  **Result: gain of reproductive advantage**
- **Neutral mutation**
  **Result: No change**
- **Production of inferior or no protein**
  **Result: Fatal (death) and/or disease causing.**

### Cause of Mutations

- **Mutagens (substances that cause mutations) such as:**
  - **Electromagnetic Radiation: X-rays, Gamma rays and UV rays**
  - **Chemicals: e.g., benzene, nicotine**
  - **Naturally occurring e.g., viruses like HPV**
- **Random Occurrence/spontaneous**

## Evidence for Mutagenic Effect of Radiation

- **Smokers have a greater risk of developing lung cancer**
- **Deformities resulting in children of nuclear accidents (who are exposed to gamma radiation) e.g., Chernobyl**
- **Rosalind Franklin and Marie Curie – both died of cancer (uncontrolled mutation) due to radiation**
- **Skin cancer due to UV sun exposure**

# What is a SNP?

- **Is a single difference in a base pair in a person's DNA**
- **To becalled a SNP this error must occur in at least 1% of the population**
- **SNPs may still lead to phenotypic change such as a change in appearance, function of an enzyme or susceptibility to disease; however, most commonly, SNPs occur in non-coding regions of DNA.**

- **There are 10 million known SNPs in the human genome; approximately every 300 bases there is a SNP!**

## Why are SNPs important?

- **SNPs are important genetic markers that can help scientists predict an individual's response to certain drugs, susceptibility to environmental factors such as toxins, and risk of developing particular diseases.**
- **A genetic marker is defined as a specific DNA sequence located at a known site on chromosome.**
- **Genetic markers include SNPs, STR (short tandem repeats) and a number of other types that doctors use to identify a person's genetic susceptibility to disease.**

***Notes:** Autosomes = chromosomes 1st – 22nd, non-sex cells.*

## Huntington's disease

- **Autosomal dominant**
- **If a person inherits more than 36 repeated CAG codons in their DNA on chromosome 4th, then that person will diagnose with HD.**

## Haplotypes (a.k.a haplogroups)

- **As the name suggests, a haplotype is a "haploid genotype".**
- **It is the particular pattern of sequential SNPs (or alleles) observed on a particular chromosome.**
- **They are a group of linked SNPs and are used:**
  - **As an indicators of disease**
  - **To establish family lineage and determine genetic relatedness of individuals**
  - **To study the evolutionary relatedness (holiday homework book)**

## Somatic vs Germline

- ***Somatic mutations* are changes to the DNA sequence that occur in body cells, therefore, those mutations can only be passed on to cells which arise from those cells, but not to the offspring of the organism. For example, your skins cells may have a mutation that gives rise to skin cancer. Those skin cells that have the mutation may pass on that mutation to subsequent cells that may arise from this mutated cell through the process of mitosis, which may lead to a growth in the skin cancer. However, a child of a person with skin cancer will not have inherited the same mutation – it cannot be inherited.**
- ***Germline mutations* are mutations that arise in sperm and egg cells (germ cells are those cells that will become gametes), which means**

**that they can passed-on to offspring of those mutated cells. Mutations from sperm and egg cells are inherited. For example, an inherited form**

## Summary

| MUTATION | GERM-LINE | SOMATIC |
|---|---|---|
| DEFINITION | Change in DNA of **germ cell** = a cell which forms sex cells | Change in DNA of **somatic cell** = a body cell |
| EFFECT (ON ORGANISM) | **None** | **All daughter cells** from the original, mutated cell will have the mutation |
| EFFECT (ON OFFSPRING) | **All cells** will have the mutation | **None** |
| EXAMPLE | **Down syndrome** | **Lung cancer** |

## Coding vs Non-coding DNA

- ***Coding DNA:*** **are areas of DNA that contain genes that code for proteins.**
- ***Non-coding DNA:*** **makes up the majority of our DNA and used to be called "junk DNA", because it was thought to do nothing. However, as more is known about the non-coding regions of DNA, scientists are realizing its importance to regulation of expression, regulation of transcription and translation, determining the start piunt for DNA replications, scaffolding of protein structures and to providing the code for other important molecules, such as telomeres and centromeres.**
- **These non-coding regions are extremely useful for scientists; for example, identification of a person in crime investigations (DNA profiling) as there are often many repeated sections in non-coding DNA and as evidence of common ancestry.**

| Non-coding DNA | Description |
|---|---|
| **Satellite DNA** | Tandemly repeating sequences of DNA (e.g. STRs)<br>Structural component of heterochromatin and centromeres<br>Commonly used for DNA profiling |
| **Telomeres** | Regions of repetitive DNA at the end of a chromosome<br>Protects against chromosomal deterioration during replication |
| **Introns** | Non-coding sequences *within* genes<br>Are removed by RNA splicing prior to the formation of mRNA |
| **Non-coding RNA genes** | Codes for RNA molecules that are **not** translated into protein<br>Examples include genes for tRNA |
| **Gene regulatory sequences** | Sequences that are involved in the process of transcription<br>Includes promoters, enhancers and silencers |

**Mnemonic:**
STING

# Genetic Change

# BIOTECHNOLOGY

## What is biotechnology?

- **The use of biological processes (in plants, animals, and microbes) to make products that are beneficial to human.**
- **This includes:**
  - **The making or modification of a product**
  - **Improvement in plants or animals**
  - **The use of microorganisms for specific uses.**

## History of Biotechnology

- **Has a long history**
- **Origin can be traced to the beginning of agriculture**
- **Human society changed from nomadic hunter – gatherers to farmers (biotechnology played a key role in this transition)**
- **Began when societies collected seeds in carious places such as South-East Adia and fertile crescent of Middle East**

- **Wild species were domesticated and were bred for characteristics that were favourable for human use (artificial selection)**
- **This was also applied to agriculture in which good seeds were cultivated for harvest, thus improving crops.**

# Implications for society and impact on biodiversity

## What are transgenic organisms?

- **Any organism that has had a gene from one organism in to another for a purpose.**
- **Example:**
  - **Golden rice – modified rice that produces beta-carotene, the precursor (approacher) to vitamin A. Vitamin A deficiency (absent) is a public health problem for millions of people around the world.**
  - **Goats that produce important proteins in their milk: goats modified to produce FDA – approved human antithrombin, which is used to treat a rare blood clotting disorder in human.**

***Notes*: Antithrombin is a small glycoprotein that inactivates several enzymes of the coagulation system.**

## Potential benefits of biotechnology

- **Increased food production (e.g., canola)**
- **Ability to grow food in substandard areas (e.g., wheat that is drought resistant)**
- **Grow food with higher nutritional content (e.g., Low GI rice)**
- **Grow crops with inbuilt herbicides and pesticides (e.g., BT Cotton)**
- **Increased range of genetic testing and screening for disease ID and diagnosis (e.g., genome sequencing)**
- **Greater range of production of proteins for medical uses (e.g., hormone replacement therapies)**
- **Gene therapy (e.g., in cystic fibrosis)**

- **Tissue and organ engineering to replace body parts**
- **Production of biofuels as an energy source**
- **Bioremediation techniques to remove contaminants in soils**
- **Improved pharmaceutical for drug treatments**
- **More efficient and less polluting processes in the textile industry.**

# Genetic Change

# BIOTECHNOLOGY

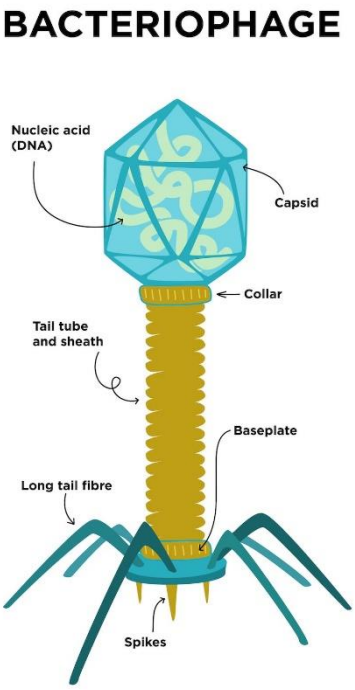
## CRISPR Cas-9

- **A gene editing tool that is the future of genetic technology due to its speed and accuracy with which it can edit DNA, that is the most efficient, easiest, fastest and cheapest gene editing.**
- **CRISPR stands for " Clustered Regulatory Interspaced Short Palindromic Repeats"**
- **In the late 1980s, scientists noticed that many bacteria, such as E. Coli and clostridium, contained many repeated DNA segments (CRISPRs) and they seemed to have a mechanism that allows the bacteria to defend themselves against virus.**

## Viruses use host DNA to copy itself and spread

**Viruses act by taking over a cell's DNA and inserting itself into the host DNA so that it can be copied.**

- **When viruses attack bacteria (these viruses are known as bacteriophages) the bacterial CRISPRs and associated proteins (CAS) form a bacterial immune response.**
- **It works by a bacterium cutting a piece of viral DNA, placing it between the CRISPR segments, transcribing it into RNA and attaching to a CAS-9 Protein.**
- **This CAS-9 protein patrols the DNA and the cell. If they recognize any genetic material from a virus that matches with the viral DNA it will destroy it, thus protecting the bacteria from infection.**




***Notes: CAS = Crispr associated proteins equivalent to a restriction enzyme a.k.a nuclease (cutting enzyme)**
**Palindromic = a word, phrase, or sequence that reads the same backwards as forwards, e.g., NEVER ODD OR EVEN**
**CAS-9 = one of the enzymes produced by the CRISPR system – binds to the DNA and cuts it (breaking its bond), shutting the targeted gene off.**

## Summary

1) **Guide RNA to direct CAS-9 to the specific gene in the genome**
2) **CAS-9 cuts the gene + triggers a normal DNA repair pathway.**
3) **New DNA can be introduced into the DNA to correct the identified mutation.**

## How it works as a gene editing tool?

- **The CRISPR-CAS9 system consists of two key molecules that introduce a change (mutation into the DNA). These are:**

- **An enzyme/protein called Cas9. This acts as a pair of "molecular scissors" that can cut the two strands of DNA at a specific location in the genome so that bits of DNA can then be added or removed.**
- **A piece of RNA called guide RNA (gRNA). This consists of a small piece of pre-designed RNA sequence (about 20 bases long) located within a longer RNA scaffold . The scaffold part binds to DNA and the pre-designed sequence "guides" CAS9 to the right part of the genome. This makes sure that the CAS9 enzyme cuts at the right point in the genome.**

Off targets changes are an issue with and editing finding the wrong location

- **The guide RNA is designed to find and bind to specific sequence in the DNA. The guide RNA has RNA bases that are complementary to those of the target DNA sequence in the genome. This means that, at least in theory, the guide RNA will only bind to the target sequence and no other regions of the genome.**
- **The CAS9 follows the guide RNA to the same location in the DNA sequence and makes a cut across both strands of the DNA.**
- **At this stage the cell recognizes that the DNA is damaged and tries to repair it. Scientists use the DNA repair machinery to introduce changes to one or more genes in the genome of a cell of interest. E.g., inserting a correctly functioning gene if it is damaged.**

## Applications and Ethics

- **CRISPR-Cas9 has a lot of potential as a tool for treating a range of medical conditions that have a genetic component, including cancer, hepatitis B or even high cholesterol.**
- **Many of the proposed applications involve editing the genomes of somatic (non-reproductive) cells but there has been a lot of interest in and debate about the potential to edit germline (reproductive) cells.**
- **Because any changes made in germline cells with be passed on from generation to generation it has important ethical implications.**

## Ethical issues with its use

- **Carrying out gene editing in germline cells is currently illegal in most countries. However, the use of gene editing technologies in somatic cells is uncontroversial. They have already been used to treat human disease on a small number of exceptional and/or life-threatening cases.**
- **It is like to be many years before CRISPR-Cas 9 is used routinely in humans.**
- **Much research is still focusing on its use in animal models for isolated human cells, with the aim to eventually use the technology to routinely treat diseases in humans.**
- **There is a lot of work focusing on eliminating "off-target" effects, where the CRISPR-CAS 9 system cuts at a different gene to the one that was intended to be edited.**

## Agarose Gel Electrophoresis

- **DNA is a negatively charged molecule and therefore is attached to positive charges.**
- **Agarose provides a matrix through which DNA molecules migrate.**
- **Larger molecule move through the matrix slower then small molecules**
- **The higher the concentration of agarose, the better the separation of smaller molecules**

## Recombinant DNA

- **Recombinant DNA technologies:**
- **Allows DNA to be combined from different sources**
- **Also called genetic engineering or trans genetics**
- **Vector DNA source which can replicate and is used to carry foreign gene and DNA fragments**

## Restriction Enzyme

**Restriction enzyme is an enzyme which binds to DNA at a specific base sequence on DNA where a restriction enzyme binds.**

- **All recognition sites are palindromes, which means they read the same way forward and backwards.**
- **After cutting DNA with restriction enzymes, the fragments can be separated on an agarose gel**
- **The smaller fragments with migrate further then the longer fragments in an electric field**
- **The bands are compared to a standard DNA of known sizes. This is often called a DNA marker or a DNA ladder.**

## Why are bacteria used?

- **They contain plasmids which are circular piece of DNA that exists apart from the chromosomes and replicates independently of it.**

## Re-Introducing the Plasmids Back

## TRANSFORMATION

- **Now the plasmids that contains the introduced gene (recombinant DNA) need to be reintroduced into the bacteria so they can multiply and make more of the gene.**
- **Can be done by combining them in a test tube with CaCl2. The high concentration of calcium ions makes the membranes of the bacteria more porous.**
- **This then allows the plasmids to move into the bacteria cells.**
- **Not all bacteria will take up a plasmid and this is why the monitoring must happen.**

## How do we know which bacteria have the gene?

- **It is necessary to isolate the host bacteria that contain the gene that has been spliced as only want the recombinant DNA (e.g., insulin)**
- **By having a gene on the same plasmid that gives resistance to an antibiotic, the other bacteria can be removed by culturing the bacteria in a medium that contains the antibiotic.**
- **The bacteria containing the resistance to the antibiotic will survive and the others will be killed by the antibiotic.**

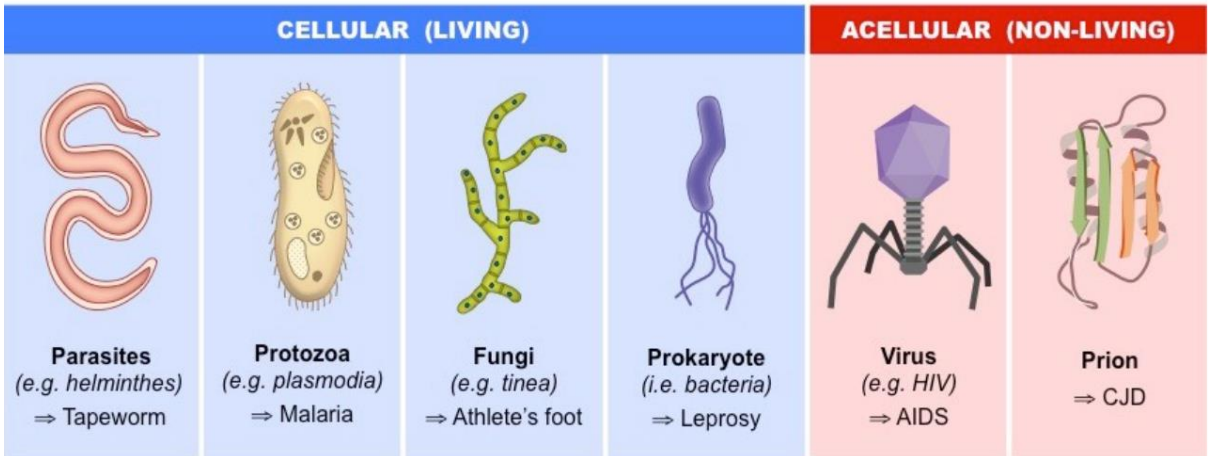
# TERM 3

## MODULE 7

# Infectious Diseases

## What are Pathogens?

<u>Types of Pathogens</u>



- **Pathogens are organisms or biogenic molecules (such as proteins) that cause diseases.**
- **They are infectious agents, meaning they can be passed from one individual to another.**
- **Pathogen often quite specific for its host and will cause a specific disease in one specific or a small closely related group of species.**

## Macroparasites

- **Larger disease-causing organisms that can be seen with the naked eye**
- **Ectoparasites – external**
- **Endoparasites – internal**
  **Example: ticks, worms, fleas**

## Protozoans

- **Unicellular eukaryotic organisms**
- **No cell walls**
- **Animal-like organisms**
- **Free-living or parasitic**

Giardia (causes gastroenteritis)

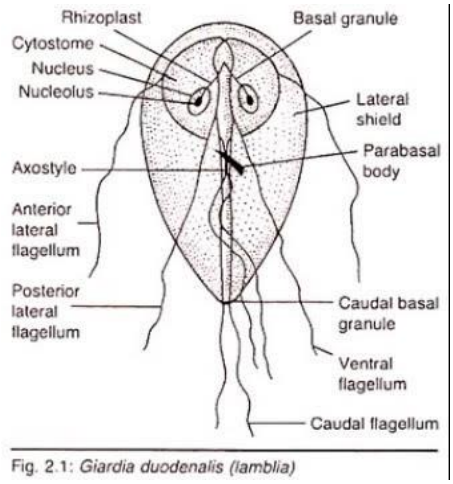
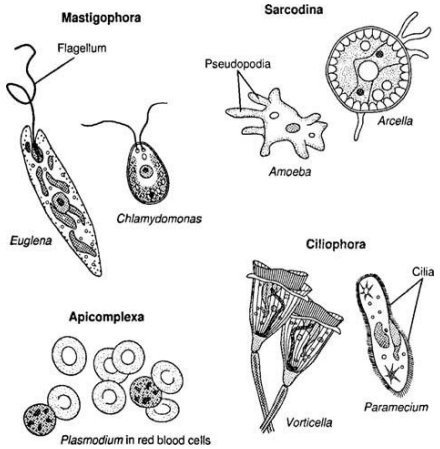


Fig. 2.1: *Giardia duodenalis (lamblia)*

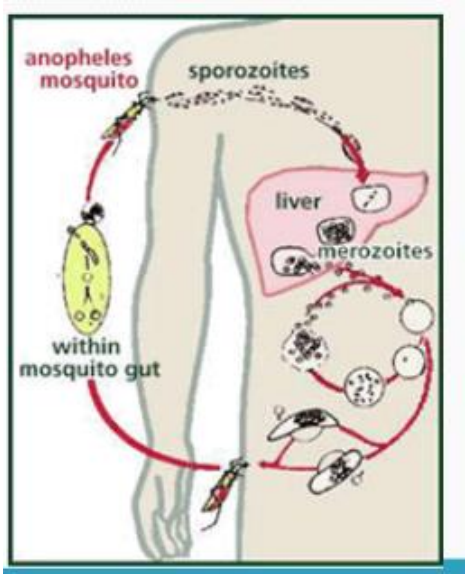
Others: amoebic dysentery, sleeping sickness




## Protozoans – Malaria

- **Caused by Plasmodium parasite (various species)**
- **Complex aetiology with a 7-stage life cycle that requires a vector (usually mosquito)**
- **Stages occur in both mosquito and humans**

Vector: an organism typically a biting insect or tick, that transmits a disease or parasite from one



## Fungi

- Eukaryotic (membrane bound organelles)
- Have a cell wall made of chitin (unlike plants – cellulose)
- Some unicellular (yeasts), most multicellular
- Also play important role in ecosystems in decomposing of organic molecules (together with bacteria)

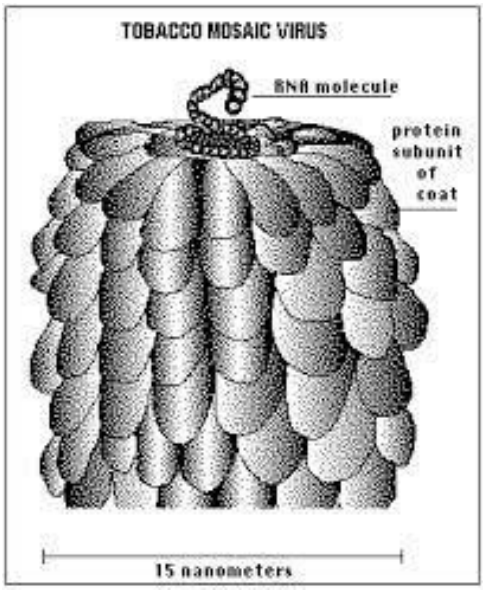

Example: ringworm, tinea, thrush

## Bacteria

- Cellular, unicellular prokaryotes with a cell wall
- Therefore, no membrane bound organelles
- Only some are pathogenic, others ar4e useful (e.g. lactobacillus acidophilus)
- Most live freely, others are parasites.
  Example: tatamis, pneumonia

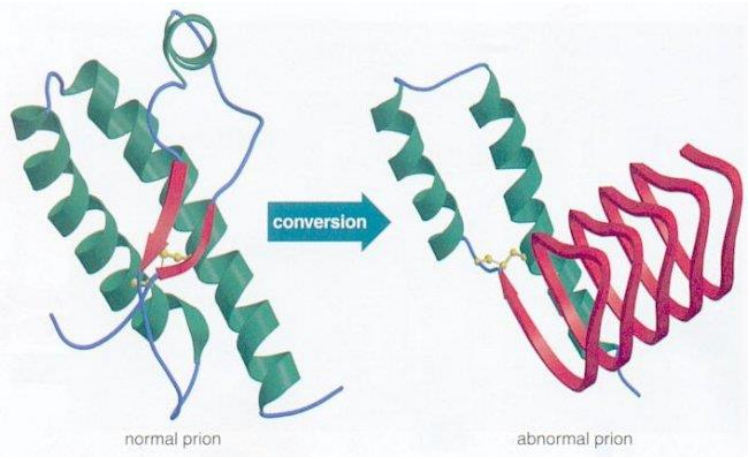
## Viruses

- Non-cellular pathogen
- A protein coat with a small amount of genetic material enclosed
- Found in both eukaryotic and procaryotic cells
- Reproduce inside hose, killing them
- No cures – vaccinations can prevent
- Anti-viral for treatment (e.g. acyclovir)
  Example: HIV, smallpox, chicken pox, influenza




## Prions

- **Non-cellular infectious agents that cause disease in mammals**
- **Contain no DNA or RNA, just proteins**
- **Can convert normal proteins to abnormal proteins.**
- **Transmissible between animals, usually by brain tissue.**




E.G Bovine spongiform encephalopathy BSE, OR Creutzeld Jacob disease (CJD is the human form of BSE – acquired through eating infected beef)

# Contributions to the Understanding of Disease

## by Louis Pasteur and Robert Koch

02/05/2023

## Summary of their contributions:

### Pasteur 1822-1895:

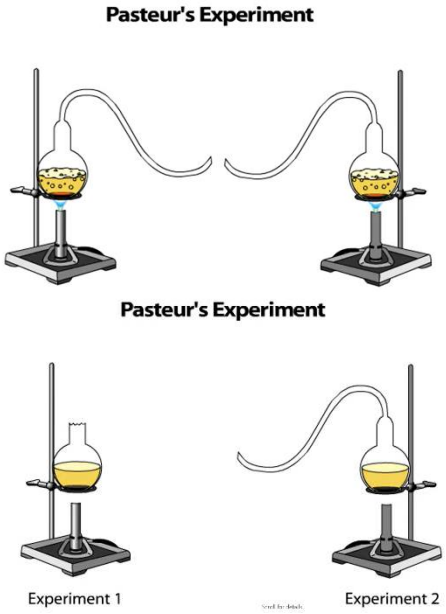
- **Founder of microbiology**
- **Established the link between a microbe and certain infectious diseases**
- **Developed the process of pasteurisation**
- **Refined the "Germ Theory of Disease"**
- **Disproved the idea of "Spontaneous Generation"**
- **Developed a vaccination to anthrax as an outcome of his testing**

### Koch 1843-1910:

- **Succeeded in identifying microbes as the cause of disease**
- **Developed a set of rules to identify the causative microbe in a disease – Koch's Postulates**
- **Identified the causative pathogen for anthrax as *Bacillus anthracis***
- **Also studied the bacteria that causes Tuberculosis and Cholera**

## Other scientists that contributed to the vaccine development:

- **Pasteur**
- **Jenner**
- **John Snow (epidemiology)**




## Pasteur's Swan Neck Flask Experiment

1. **Sterilise two swan-neck flasks, containing a nutrient broth, by boiling.**
2. **Snap off the neck of one of the flasks, thereby exposing the broth to the outside air, but not the other flask.**
3. **Overtime, the flask which was exposed to dust particles (that may contain microbes), that have entered due to gravity, became cloudy with microbial growth.**
4. **The swan neck flask remained sterile for years as no microbes could enter as they were trapped in the neck of the flask.**

## Pasteur's work with anthrax and vaccination

- **Pasteur showed that anthrax was caused by a rod-shaped bacterium.**
- **He developed a weakened strain of bacterium and produced the first vaccination from it**
- **He took 50 sheep and inoculated (prevent disease through vaccination) 25 of them with the weakened strain.**
- **After the sheep recovered, he injected all the sheep with normal anthrax bacterium**
- **Only the 25 un-vaccinated sheep died.**

## Pasteur's work with fermentation

- **Pasteur examined samples of fermenting wines under a microscope**
- **He observed YEASTS (fungi), which he hypothesised, were converting sugars in the wine into alcohol**
- **He also showed that bacteria were responsible for the souring of beer and milk, where they converted sugars to lactic acid to sour it**

- **Devised a method to remove bacteria from milk by boiling then cooling it. A method now known as *Pasteurisation.***
- **His work has led to many of the simple hygiene practices we use today.**

### Koch's Postulates (to determine the cause of a disease)

1. **Pathogen must be found in the hose in every case**
2. **Pathogen must be isolated from the host and grown in pure culture (petri dish with growth medium)**
3. **When placed in a healthy hose, the pathogen produced in pure culture must cause the disease in the host.**
4. **Pathogen must be isolated from the new host and shown to be the original pathogen.**

## Adaptations of different pathogens that facilitate transmission between hosts

### Pathogens must be able to transfer between hosts

1. **To cause disease all pathogens must colonise their specific host, avoid immune systems, multiply and then be able to spread themselves to other hosts.**
2. **Many pathogens are termed "intracellular" as they enter cells, and it is here that they survive and multiply**
3. **The ability to cause disease in a host is called pathogenicity and virulence is the degree to which the pathogen causes disease**
4. **A pathogen with high virulence has properties that enable it to bring about a high level of disease in a host**
5. **Humans are vulnerable to penetration by pathogens in four main ways:**
    - **Respiratory surfaces : air borne pathogens may enter the mouth and nose and be absorbed across mucous membranes of the respiratory surfaces.**
    - **Wounds: the skin generally provides a good proactive barrier to microbes but if skin is broken, as in a cute, then pathogens can enter.**

- **Digestive system: if food is contaminated then pathogens can enter via mouth and enter the digestive system.**
- **Reproductive organs: urethra in males and females and vagina in females. Sexually transmitted pathogens can enter across mucous membranes.**

## Adaptations

| Adaptation | Example: How does this adaptation help the pathogen? |
|---|---|
| Vector | Plasmodium falciparum (Malaria) uses mosquitoes as a vector |
| Physical Characteristics | Pili – small, hairlike projections on bacteria that stop them from being washed away in the gut |
| Ability to withstand harsh environments | Some bacteria thrive in acidic environments – Helicobacter pylori – this bacterium is found in the stomach and causes stomach ulcers |
| Forming a biofilm | Staphylococcus aureus (golden staph) is a bacterium that can lay dormant by producing a biofilm that is resistant to antibiotics. |
| Toxin Production | Bordetella pertussis (whooping cough), produces toxins that damage respiratory cells |
| Binding to host-cell receptors | Most viruses access the cell's reproduction mechanisms by binding directly to cell membrane protein to enter the cell – e.g., SARS-CoV2 uses the ACE2 receptor which is found in many human cells – particularly in the lungs |
| Living inside white blood cells (immune cells) | Tuberculosis (Mycobacterium Tuberculosis) is phagocytosed by WBC and forms a capsule like structure called a tubercule, allowing it to be protected and survive for decades |

| | |
|---|---|
| **Changing host cell normal function** | **Many pathogens that cause diarrhoea, colds and sneezing are assisted by causing their host cells to expel them to aid distribution.** |
| **Changing antigens (produces an immune response)** | **Many pathogens can change the shape of their antigens to avoid detection by the host or require the production of a new vaccine every year (eg. Common cold)** |
| **Transferring resistance** | **Many bacteria are able to transfer resistance genes to avoid being killed by antibiotics** |

# Introduction to Disease

# (Atomi)

## What is Disease?

- **A condition that impairs the normal functioning of an *organism* (e.g., animals, plants, or human)**

## Types of Diseases

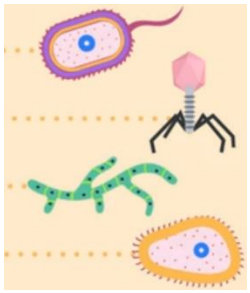
### 1. Infectious

- **Contagious conditions that impair the functioning of an organism**
  - **They can be transmitted from one organism to another**
  - **They are caused by pathogens**

- **Caused by pathogens → any organism which is capable of causing disease**

EXAMPLES
- Common cold
- AIDS
- Malaria

- **BACTERIA**
- **VIRUSES**
- **FUNGI**
- **PROTISTS**



BAD microbes which are able to grow in other organisms and interrupt normal functioning

### 2. Non-Infectious

- **Non-contagious diseases which can't be transmitted from one organism to another**

- Caused by factors → not pathogens !!!


## SUMMARY

**Disease** is a condition that impairs the normal functioning of an organism. There are 2 types of diseases: infectious and non-infectious

| | INFECTIOUS | NON-INFECTIOUS |
|---|---|---|
| NATURE | CAN be transmitted from one organism to another | CAN'T be transmitted from one organism to another |
| CAUSE | Pathogens | Genetic and lifestyle factors (e.g., nutrition/environment) |

## Comparison between fungi and viruses

### Estimated:

- Pest + disease destroy 30% - 40% of plants of human consumption

### Fungi:

- Eukaryotic heterotrophic organisms; cells with cell wall
- Some unicellular, most are multicellular
- um to mm
- Fungal plant pathogens generally secrete enzyme to digest the plant cell wall matrix and enter via the stomata and "steal" nutrients from the surrounding cells. They can also inhibit cellular processes, including photosynthesis, water and nutrient uptake.

## Virus:

- **Non cellular**
- **Contains DNA, RNA and protective coat**
- **Requires a li9ving host cell to replicate**
- **Less than 500nm**
- **Viral plant pathogens are spread via vectors due to their inability to pass through plant cell walls. They can cause isolated infections or spread through out the plant can inhibit cellular processes, including photosynthesis, water and nutrient uptake.**

# SYMPTOMS OF FUNGAL AND VIRAL PLANT INFECTIONS

### Theory:

**Plant pathogens are broken into two broad groups: biotrophs and necrotrophy**

### Symptoms of viral plant infections:

- **Chlorosis (yellowed leaves)**
- **Mosaic leaf pattern**
- **Crinkled leaves**
- **Growth stunting**
- **Leaf spot**

**Examples provided here:**

### Symptoms of fungal plant infections

- **Chlorosis**
- **Leaf and stem wilting**
- **Leaf and stem rusting**
- **Leaf blotching**
- **Leaf mildew**

## PHYSICAL BARRIERS

### Theory

**Plants have a combination of both physical and chemical defence mechanisms to prevent the entry or inhibit the spread of pathogens.**

### Physical barrier (1st line of defence) prevent entry

- **Cell walls contain lignin and cellulose**
- **Waxy epidermal cuticles**
- **Bark**
- **Stomata can be closed when signalled**

## CHEMICAL BARRIERS

### Theory

**Plants lack the mobile immune cells and adaptive immune system found in mammals. As a result, if pathogens gained entry, each plant cell must work independently or in harmony with those directly associated with it to respond to invading pathogens.**

**While plants lack an adaptive immune system, they do possess an innate immune system which involves a rand of cell and chemical mediated defences.**

## AUSTRALIAN NATIVE PLANT

### Basket Grass

- **Found Australia wide, except for WA and NT**
- **Grows sandy soil and can tolerate dryness**
- **Leaves are glossy, green, shiny flat and firm.**
- **Leaves are 40-100cm long (used for weaving in Indigenous Cultures)**
- **Flowers are in clustered bunches**

## Pathogen : Phytopthera cinnamon

### Fungal pathogen

- **Causes root rot**
- **A soil-borne water mould (fungus)**
- **Wide-spread disease and very invasive in over 70 countries**

- Impacts many Australian ecosystems and affects many Australian native species.

## How does Lomandra response?

1. Production of reactive oxygen species
2. Production of hydrogen peroxide $H_2O_2$

Chemicals to kill affected cells

3. Callose formation (new cell wall formation)
4. Lignin formation (woody component of roots)

Physical barriers to stop contagion

Chemicals to stop further infection and kill affected cells so they don't spread

5. Mass production of defence proteins at the site of infection and phytoglexins
6. Production of defence hormones (e.g., salicylic acid and abscisic acids)
7. Hypersensitive responses, or rapid cell death, near the invasion site (by $H_2O_2$) production

**These responses act to inoculate the plant to further infection. This occurs through killing of fungal spores ($H_2O_2$) and the creation of a protective barrier through callose and lignin production.**

## COMPARE PLANT AND ANIMAL DEFENCE MECHANISMS

| | SIMILARITIES | DIFFERENCES |
|---|---|---|
| PLANTS | - Non-specific defenses hypersensitive response involve protein + R-genes to kill themselves so the infection does not spread. | - No specific response |
| MAMMALS | - Non-specific barrier + inflammation (e.g., skin, saliva, acid, inflammation non-specific WBC) | - Specific 3rd line<br>- Humoral and cell-mediated responses<br>- Involving antigen/antibody responses<br>- Memory B + T cells ensure long-term immunity |

**BIOLOGY TERMS**

1. **Macrophage: large non-specific white blood cell**
2. **Antigen: anything that triggers an immune response**
3. **APC: antigen presenting cell (WBC – non-specific)**
4. **Humours: body fluids blood/plasma/interstitial fluid**
5. **Innate: what is already in our body**

# FIRST LINE DEFENCES/INNATE $ NON-SPECIFIC IMMUNE SYSTEM

## Skin

- **Acts as a barrier to invasion**
- **is keratinized (protein)**
- **has a tough, dry, and waterproof outer coating**
- **contains chemicals to destroy invading organisms**
- **when unbroken, skin prevents the entry of pathogens**
- **Pores in the skin secrete substances that kill bacteria (e.g., sebaceous glands excrete sebum).**

## Mucous membranes

- **Line the digestive, respiratory, reproductive and urinary tracts with antigen containing mucus.**
- **Tears and saliva wash over the membranes**

## Tear

- **Have lysozyme, an enzyme which acts to break down the cell wall of pathogens (Chemical Barrier)**

## Saliva

- **Also have lysozyme (Chemical Barrier)**

## Cilia

- **Fine hairs in the nose and ears that aid in preventing the entry of pathogens. Often in combination with wax and/or mucous**

## Other Chemical barriers

- **Sweat – has chemicals which can kill different pathogens. Acidic conditions kill some pathogens.**

- Stomach acid – destroys pathogens

## Other bodily secretions

- Semen (male) – contains spermine – antibacterial
- Vagina – mucus membrane – acidic
- Urethra – acidic (due to acidic urine); washing action of urine

## SECOND LINE DEFENCES

- If a pathogen is able to get past the body's first line of defense, and an infection starts, the body can rely on it's second line of defense.
- This will result in what is called a non-specific response
- Identify defence adaptations:
    1. Inflammation response
    2. Phagocytosis
    3. Lymph system
    4. Cell death to seal off pathogen

## Inflammatory response

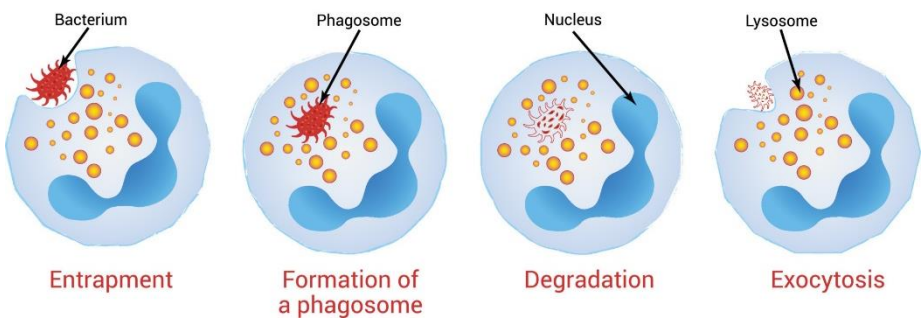
- Redness – due to capillary dilation resulting in increased blood flow, a.k.a – vasodilation
- Heat – due to capillary dilation resulting in increased blood flow
- Swelling – due to passage of plasma from the blood stream into the damaged tissue

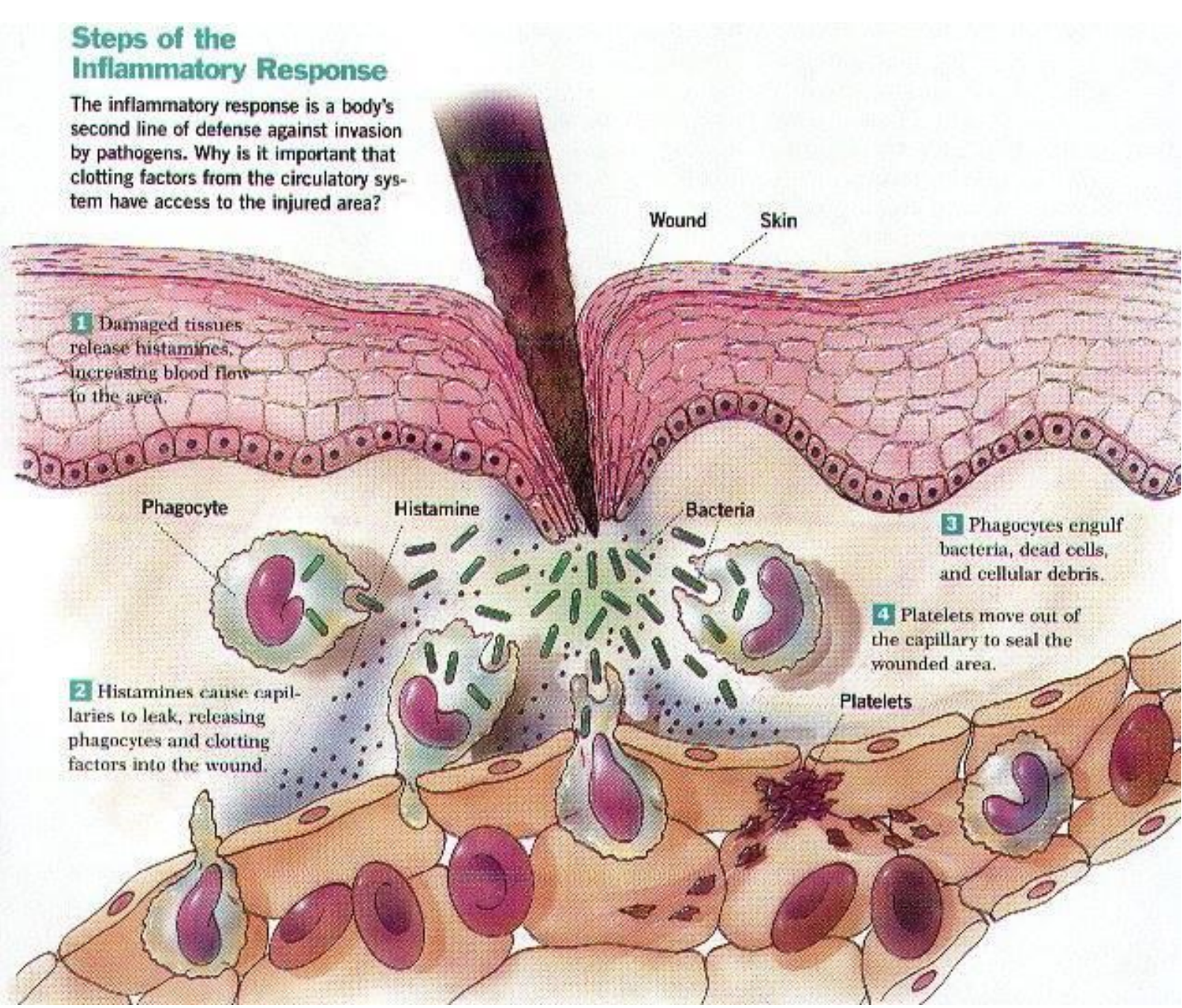
Due to histamine release

- Pain - due mainly to tissue destruction and , to a lesser extent swelling
- Release of white blood cells (phagocytes) into affected area from the capillaries
- Clotting due release of clotting factors and platelet activity

## Phagocytosis

- Inflammation attracts phagocytes (non-specific large WBC) to the area
- They surround the pathogen (or other cellular debris) and ingest it
- This forms a phagosome – enzymes are released to breakdown the pathogen into harmless products






## Lymph system

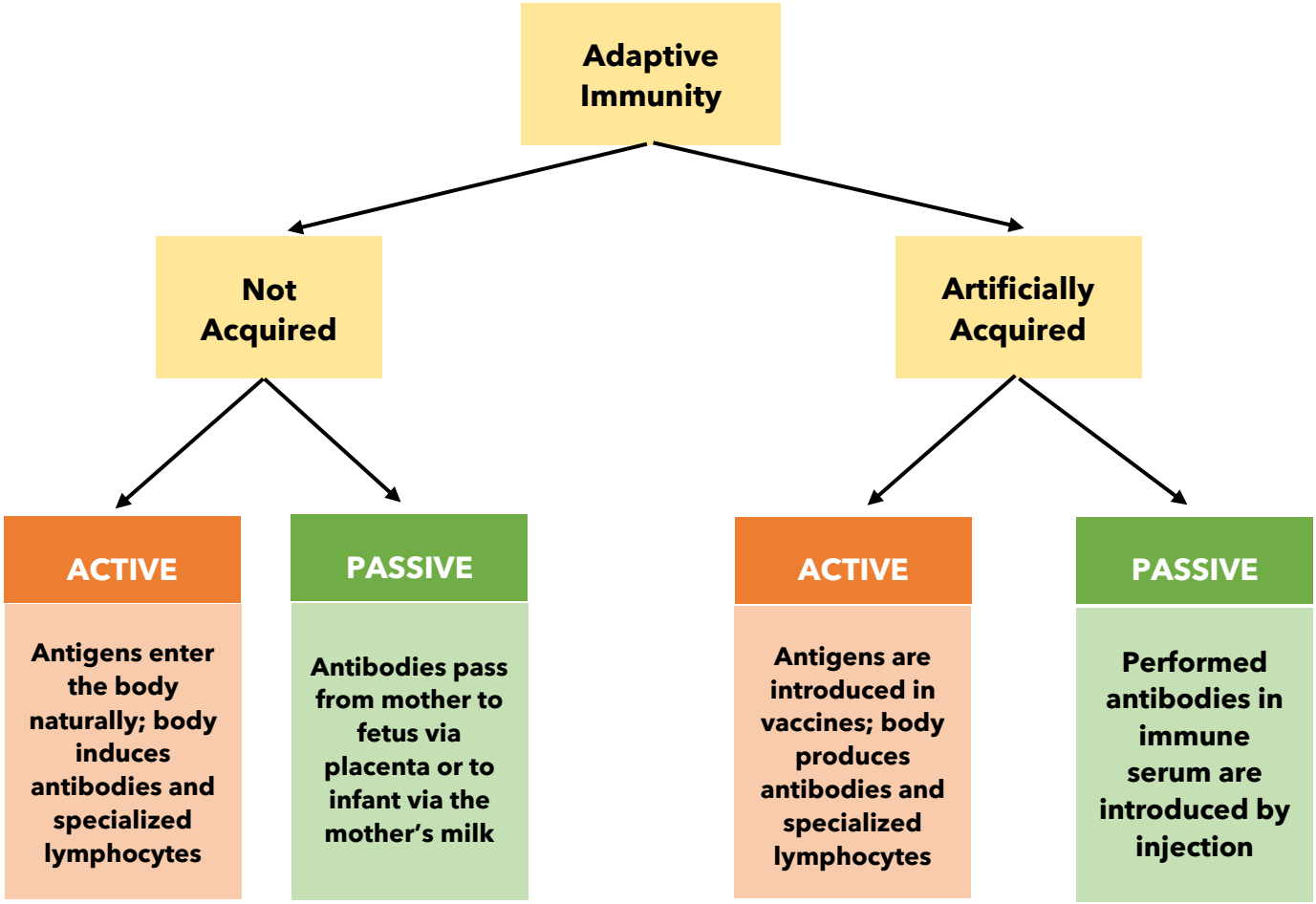
- **A system of vessels that begins near the capillaries and run parallel to the veins**
- **Important for 2nd line defense as it stores non-specific white blood cells**
- **Empty into the veins before they reach heart**
- **Contain fluid called LYMPH**

## Cell death to seal off pathogen

- **Produced in some diseases only, e.g., tuberculosis and leprosy**
- **When a body is unable to neutralize an antigen, it can seal off pathogens in a cyst, or within a group of cells**

- **This cluster of cells, also a granuloma (on skin), is made of a core of dead tissue, surrounded by layers of macrophages, then lymphocytes, the fibroblasts which produce a tough outer wall.**

## HOW DOES THE HUMAN IMMUNE SYSTEM REPSOND TO EXPOSURE TO A PATHOGEN



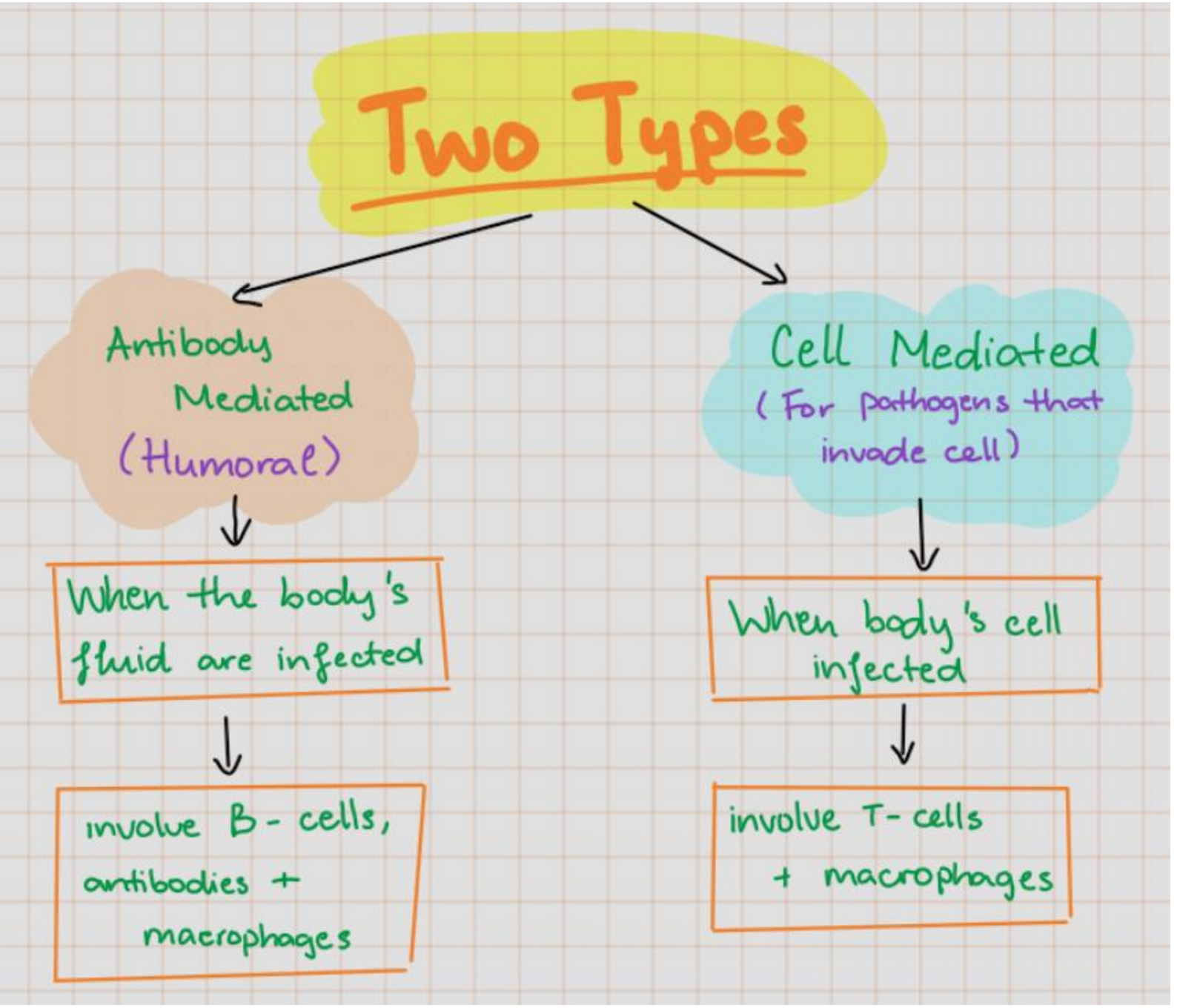
# IDENTIFY THE COMPONENTS OF THE IMMUME RESPONSE

## THIRD LINE DEFENCES

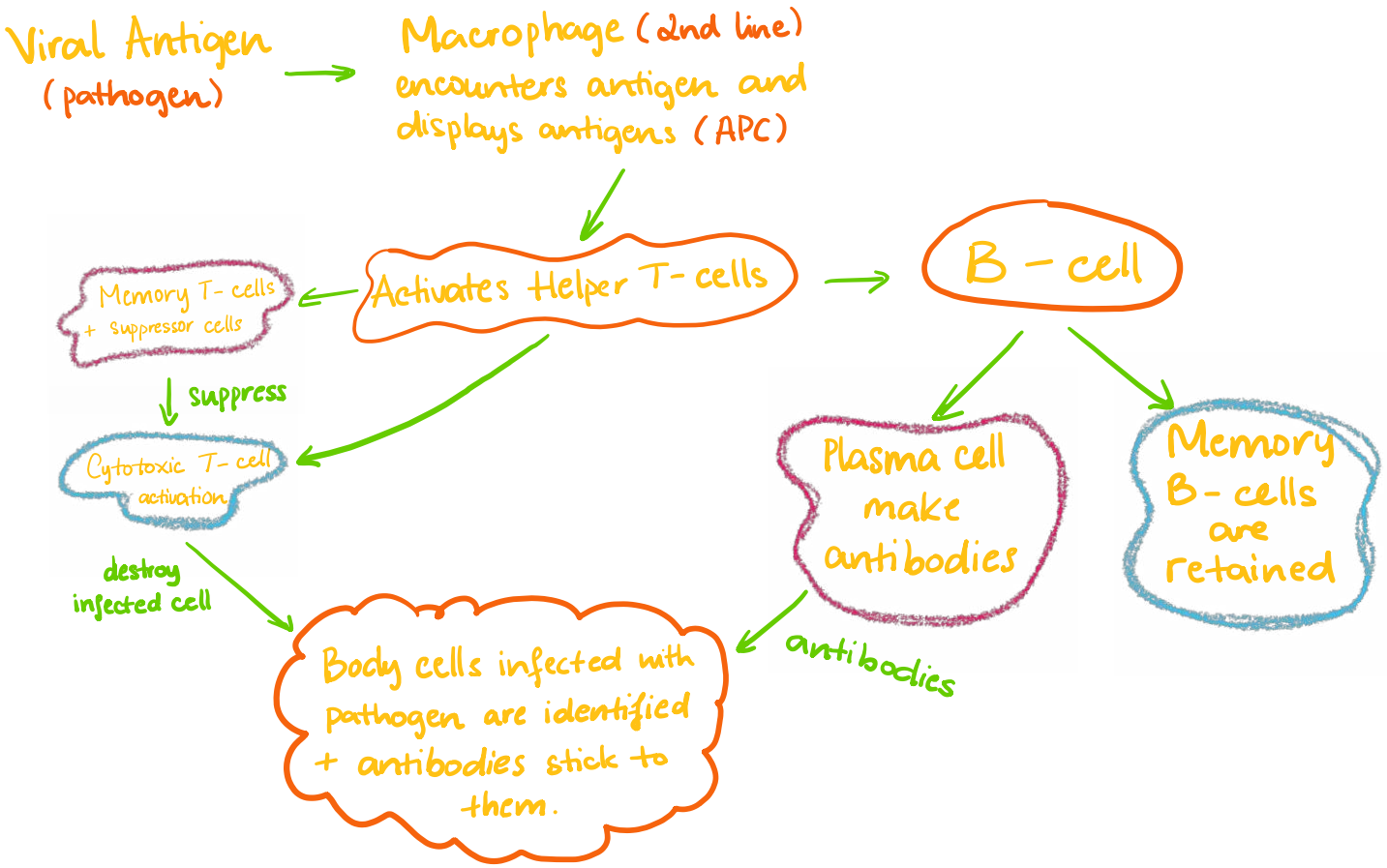
- **Is acquired (develop over time) and specific (related to a particular pathogen/antigen)**
- **It has a memory – that means that the cells can recognize antigens from previous infections, and therefore can react more efficiently with second and subsequent attacks.**

| Criteria | B-cells | T-cells |
|---|---|---|
| **Made in?** | **Bone Marrow** | **Bone Marrow** |
| **Matures in?** | **Bone Marrow in long bones** | **Thymus gland** |
| **Acts in?** | **Blood and interstitial fluids** | **Cells** |
| **Roles** | **Produce antibodies to antigens** | **Varied – depending on what they differentiate into** |
| **Activated by** | **Helper T-cells** | **Antigen presentation on macrophages (2nd line)** |
| **Types and functions?** | - **Plasma cells – activated by Helper T-cells to produce antibodies**<br>- **Memory B-cells to recognize the pathogens' antigens for future (faster) response** | - **Helper T-cells – Activate killer T-cells and B-cells**<br>- **Cytotoxic Killer T-cell**<br>- **Memory T-cell**<br>- **Suppressor T-cell: suppress B-cell and T-cell numbers** |

# HOW DOES THE HUMAN IMMUNE SYSTEM REPSOND TO EXPOSURE TO A PATHOGEN



**The antibody's shape matches a pathogen's shape, thereby binding to it and facilitating phagocytosis by macrophages**



# HOW DO B-CELLS AND T-CELLS INTERACT

- **Successful defence of the body relies upon the interaction between the cell-mediated immune response (T-cells) and the antibody-mediated (humoral) response (B-cells).**
- **The mechanism of how they interact was shown by MacFarlane Burnett, *the Clonal Selection Theory.***

## MAJOR HISTOCOMPATIBILITY COMPLEX

| MHC1 | MHC2 |
|---|---|
| - **Found on all mammalian nucleated cells (cells with a nucleus)**<br>- **Are endogenous cell membrane proteins that allow the immune system cells (macrophages, dendritic cells and helper T-cells) to regconise the cell as being self.** | - **Are proteins found on immune cells that have infested (via phagocytosis) a broken down a pathogen, displaying parts of this pathogen's antigen on the outside.**<br>- **This enables HELPER T-cells to regconise non-self-antigens and commence the immune response by the release of cytokines.** |

## WHAT HAPPENS WHEN AN ANTIGEN ENTERS THE BODY?

- **Antigen travels in the blood**
- **Engulfed by a macrophage (but doesn't consume it)**
- **Proteins (antigens) from the pathogen are broken down by the macrophage into smaller peptides and then displayed on the macrophage surface.**
- **B-cells can regconise free antigens in the blood and also display pathogen antigens in the form of peptides (MHC2 proteins)**

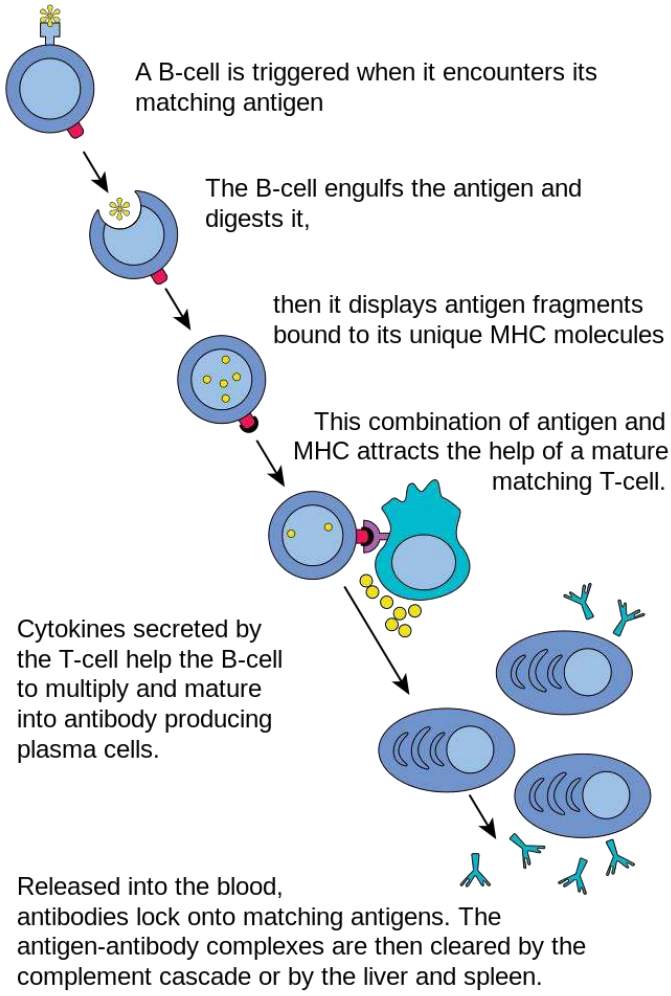
## REGCONITION OF ANTIGEN BY T-CELLS AND ANTIBODY PRODUCTION BY PLASMA B-CELL

- **The antigen peptides (MHC2 proteins on the outer surface of the macrophage allows helper T-cells to recognize them as foreign.**

- **Helper T-cells then stimulate B-cells through the production of cytokines and interleukin to clone specifically for that antigen to produce enough antibodies to kill it.**
- **The antibodies then combine with the pathogens displaying the antigens so to make them easier to kill, wither by phagocytosis, by killer T-cells, or by agglutination (clumping together to make it easier to identify + be destroyed), precipitation (changing outside that the infected cell + again easier to be identified by cytotoxic T-cells or antibodies) or engagement of the complement system (part of the inflammatory response).**

## CYTOKINES AND INTERLEUKINS

- **Cytokines are proteins made in response to pathogens and other antigens that regulate and mediate inflammatory and immune responses. Interleukin production is a self-limited process (part of the innate immune response).**



# THE ADAPTIVE IMMUNE SYSTEM (PART 1)

## ANTIBODY-MEDIATED IMMUNITY

1. **B Lymphocytes (B cells): a type of white blood cell which is produced in the bone marrow.**

   ➔ *They are **produced** and **mature in the bone marrow**. They stay in the bone marrow, where they mature.*

   ➔ ***Once matured**, B lymphocytes are officially ready to **join the battle against pathogens** and **are released to the blood.***

   ➔ *They **accumulate in the lymphoid tissues** like the lymph nodes and the spleen – where they **patiently wait for pathogens to break into the body**.*

   ➔ *When a B lymphocyte comes into contact with a [specific antigen], it **becomes activated.***

   → Because each B lymphocyte is triggered by a single, specific antigen!

   ➔ ***Once triggered by an antigen**, it begins to **proliferate** to form millions of clones – when they start to divide rapidly to form plasma cells and memory B lymphocytes.*

2. **Types of B Lymphocytes**

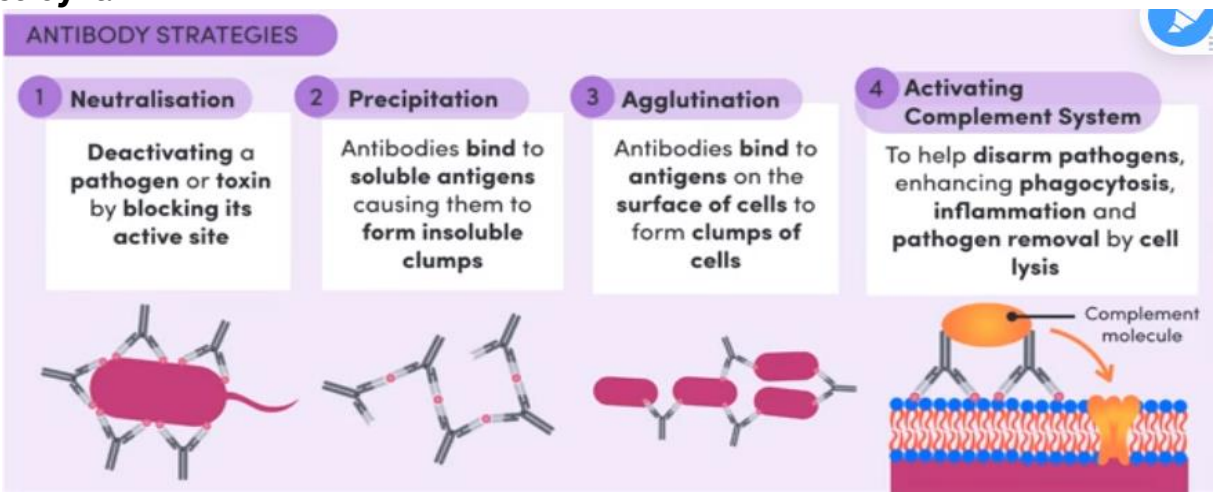
- **PLASMA CELLS**

  ➔ ***Produce antibodies** – are **Y shaped proteins** which **bind to specific antigens which triggered the B lymphocytes** where the antibody will bind to.*

  ➔ *These **antibodies then migrate to the infected areas** of the body, then **using it shape** that's compatible with the antigen which **allows it to bind to it** and **form antibody-antigen complex.***

***Antibodies interfere with the functioning of a pathogen in a way the either:**

1. **The pathogen is unable to cause damage**
2. **It is easier for other components of the immune system to destroy it.**

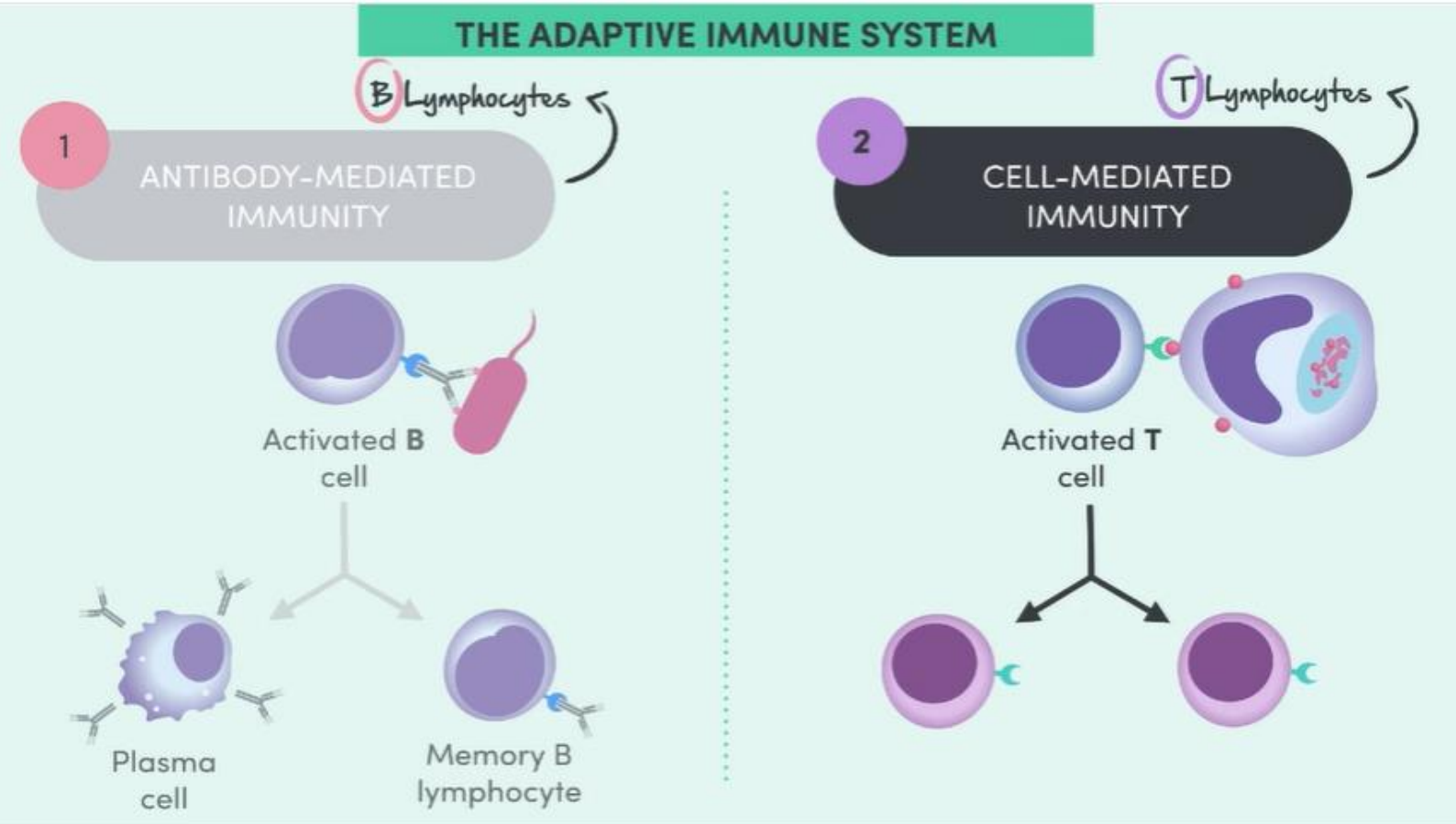


- **MEMORY B LYMPHOCYTES**
  - ➔ ***Provide immunological memory***
  - ➔ ***Long term defence against antigens***

***If the animal is exposed to the same antigen again, memory cells regconise it and divide to produce antibody.**

***This means that the immune response to an antigen that your body has already met before is faster, stronger, and longer lasting.**

## THE ADAPTIVE IMMUNE SYSTEM (PART 2)




### CELL-MEDIATED IMMUNITY

#### 1. T Lymphocytes (T cells)

➔ *They are **produced in the bone marrow.***

B cells (mature in bone marrow)

T cells (mature in thymus gland)

➔ *They are then **released into the blood** and **mature in the thymus gland***

➔ *Once matured, they're **released again into the blood** where they **circulate in an inactive state***

Every T lymphocyte is covered with slightly different kinds of receptors.

These receptors allow T lymphocyte to bind to a specific antigen.

➔ *If a [T lymphocyte] comes **into contact** with its specific antigen, the receptor on its surface allows it to bind it and **the cell becomes activated**.*

## 2. Types of T Lymphocytes

- **CYTOTOXIC**

# B LYMPHOCYTES

- **Are white blood cells, formed and mature in bone marrow**
- **When matured, get released to bloodstream, and circulate through blood and lymph**
- **Are found concentrated in lymph nodes, tonsils, Peyer's patches, and spleen**
- **B cells provide antibody mediated (humoral) immunity**

## Humoral Immunity

**Does not develop until after invasion by a pathogen or toxin. Most invading organisms are first phagocytosed and partially digested by macrophages. The macrophages become antigen presenting cells and also secrete cytokines** *(e.g., interleukin to promote growth and reproduction of specific lymphocytes)***. The antigen is bound and displayed on the major histocompatibility complex (MHC) molecule which is a cell surface molecule.**

## B Lymphocytes Receptor

**B lymphocyte has antigen receptors for only one type of antigen and all the receptors recognize the same epitope. The epitope (also called the antigenic determinant) is the small accessible region of an antigen to which the antibody or antigen receptor binds. A single B lymphocyte can have about 100 000 antigen receptors.**

**B cell receptor is a Y shaped molecule with the long tail of the Y shape consisting of 2 have chains that are anchored in the plasma membrane of the cell. Each B cell receptor has 2 antigen binding sites - one at each end of the short arms of the Y shape. Secreted antibodies are similar to the B cell receptors having the same Y shape and same antigen binding sites but antibodies lack the transmembrane regions that are present in the B cell receptors.**

**Questions:**

1. **Where are B cells formed and where do they mature?**
   - **B cells formed and mature in bone marrow**

2. **When does a specific humoral immunity develop?**

- **Humoral immunity system develops after invasion by a pathogen or toxin.**

3. **Outline the first step that usually occurs when a new pathogen or toxin enters the body.**

## CULTURAL PERSPECTIVES OF DISEASES

**Culture refers to the integrated patterns of human behavior, including the language, thoughts, actions, customs, beliefs, values and institutions of racial, ethnic, religious or social groups.**

**Cultural beliefs have the ability to impact attempts tio prevent and contain disease:**

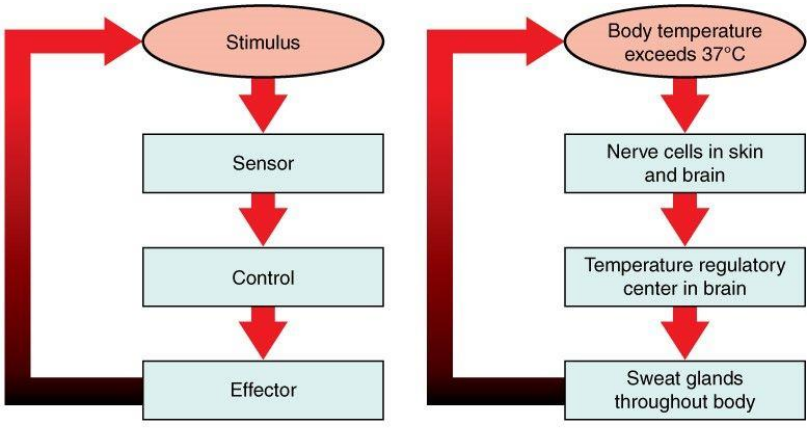
- **Ebola outbreak in Africa was able to spread as a result of famine and poverty, however, the cultural ritual of paying respect to the dead through close contact with the body also contributed to the spread of the disease.**

## Function of The Nervous System in Coordination

1. **The ultimate goal of homeostasis is the maintenance of equilibrium around the set point.**
2. **While there are normal fluctuations from the set point, the body's system will usually attempt to revert to it**
3. **A change in the internal or external environment (a stimulus) is detected by a receptor; the response of the system is to adjust the deviation parameter toward the set point.**

### THE NERVOUS SYSTEM

1. **It *detects* information about an animal's internal and external environment**
2. **It *transmits* this information to *a control center***
3. **The information is processed in the control center, generating a *response* to ensure the maintenance of a relatively constant internal state**




(a) Negative feedback loop

(b) Body temperature regulation

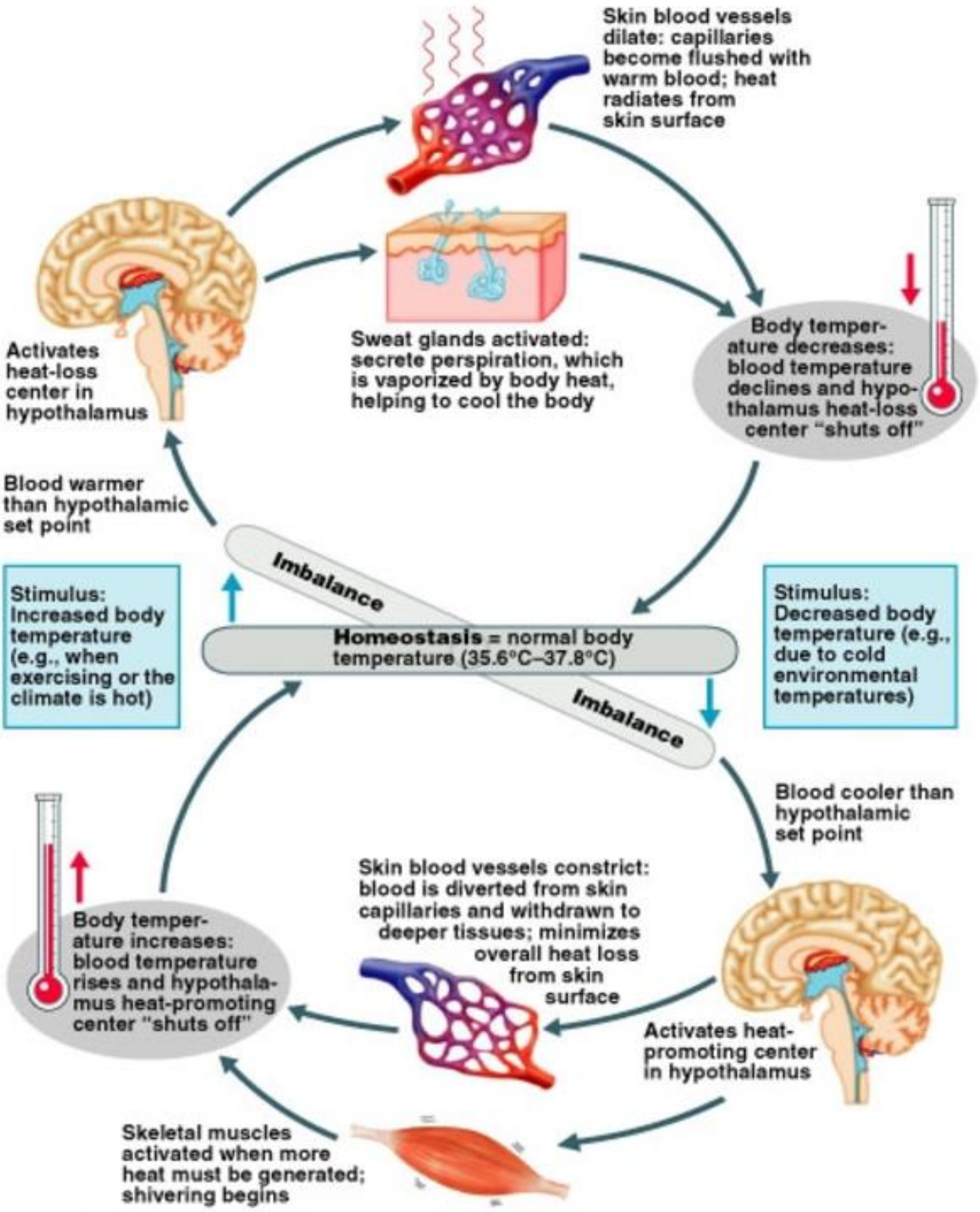
## COMPONENTS OF NERVOUS SYSTEM

1. ***Receptors*** – **sensory cells, sometimes in sense organs (for example, olfactory receptors in the nose)**
2. ***A control center (the hypothalamus)*** – **the central nervous system, which includes brain and spinal cord**
3. ***Effectors*** **(e.g., muscles and glands) – part of the body that responds to the control center's instructions**
4. ***Nerves*** – **which link all the other parts, replaying messages from one part to another in the form of electrochemical nerve impulses.**

## COMPARISON OF NERVOUS & ENDOCRINE SYSTEMS

| | Nervous system | Endocrine System |
|---|---|---|
| **Mode** | **Electrical → Chemical** | **Blood bone** |
| **Messengers** | **Neurotransmitters** | **Hormones** |
| **Release** | **Close to cell of influence** | **Distant to cell of influence** |
| **Target cells** | **Specific location (only at nerve supply)** | **More widespread** |
| **Speed** | **Fast** | **Slow** |
| **Duration** | **Short** | **Long** |

*Figure 1 THERMOREGULATION - Temperature control feedback loop*



# WHAT ARE ADAPTATIONS?

- **An adaptation is a trait of an organism that helps it to survive and to produce fertile offspring. They are maybe:**
    - **A physical or structural trait: a characteristic which is able to be inherited from parents to their off springs**

## ENDOTHERMIC ADAPTATIONS

- **Endotherms maintain their body temperature through metabolism, which is defined as the sum of all chemical reactions in the organisms**
- **Many animals regulate their body temperature through behavior such as seeking sun or share or huddling together for warmth (penguins)**
- **Endotherms can alter metabolic heat production to maintain body temperature using both shivering and non-shivering thermogenesis (heat generation)**
- **Vasoconstriction - shrinking - and vasodilation – expansion – of blood vessels to the skin can alter an organisms' exchange of heat with the environment.**
- **A countercurrent heat exchanger is an arrangement of blood vessels in which heat flows from warmer to cooler blood, usually reducing heat loss.**
- **Sime animals use body insulation and evaporative mechanisms, such as sweating and panting in the body regulation.**