Life's Common Challenges

Response: Defense

Life's Common Challenges

Introduction to Defense

Main Idea

- *Life is faced with a number of threats.*
  - *These threats include biotic factors like predators, pathogens, and parasites.*
  - *Even extreme abiotic factors can threaten the life.*
- *Living organisms defend themselves by using four general strategies protective barriers, fleeing, hiding, or fighting back.*
  - *Adaptations have resulted in numerous specific strategies that are both unique and fascinating.*

Animals

Defense

Preface to Animal Defenses

- ***Animals face threats at both the organismal level and at the cellular.***
  - ***Predators attack the organism itself.***
  - ***Pathogens and parasites attack the cells of the organism.***
- **This presentation will address defense mechanisms against predation and defense against pathogens separately.**

Animal Defenses against Predators

- **DETECTION**
- **Prey must posses great senses in order to respond to the threat of predators.**
- In some cases general cues like any abrupt movement may be enough.
- In other cases specific cues like a scent or color pattern are needed
- Many rely on multiple cues in order to assess the level of threat
  - *visual- detect identity and intentions*
  - *auditory- detect presence, proximity, identity and direction of travel*
  - *chemical- scents of predators or recently killed prey*
  - *tactile- vibrations can reveal the presence of threat*

Animal Defenses against Predators

- **FLEEING**

- **Some animal prey species rely on speed, agility and stamina in order to elude predators.**

- **However this is far more successful if the predator is detected from afar.**

- The closer the predator is the less likely it is for the prey to escape.

Animal Defenses against Predators

- **PROTECTIVE BARRIERS**

- The first and most fundamental barrier is the plasma membrane itself.

    - Membranes will discussed later at this point the focus will remain on the animal itself

- **Animal barriers include skin, armor, scales, fur, feathers, hair, mucous and saliva.**

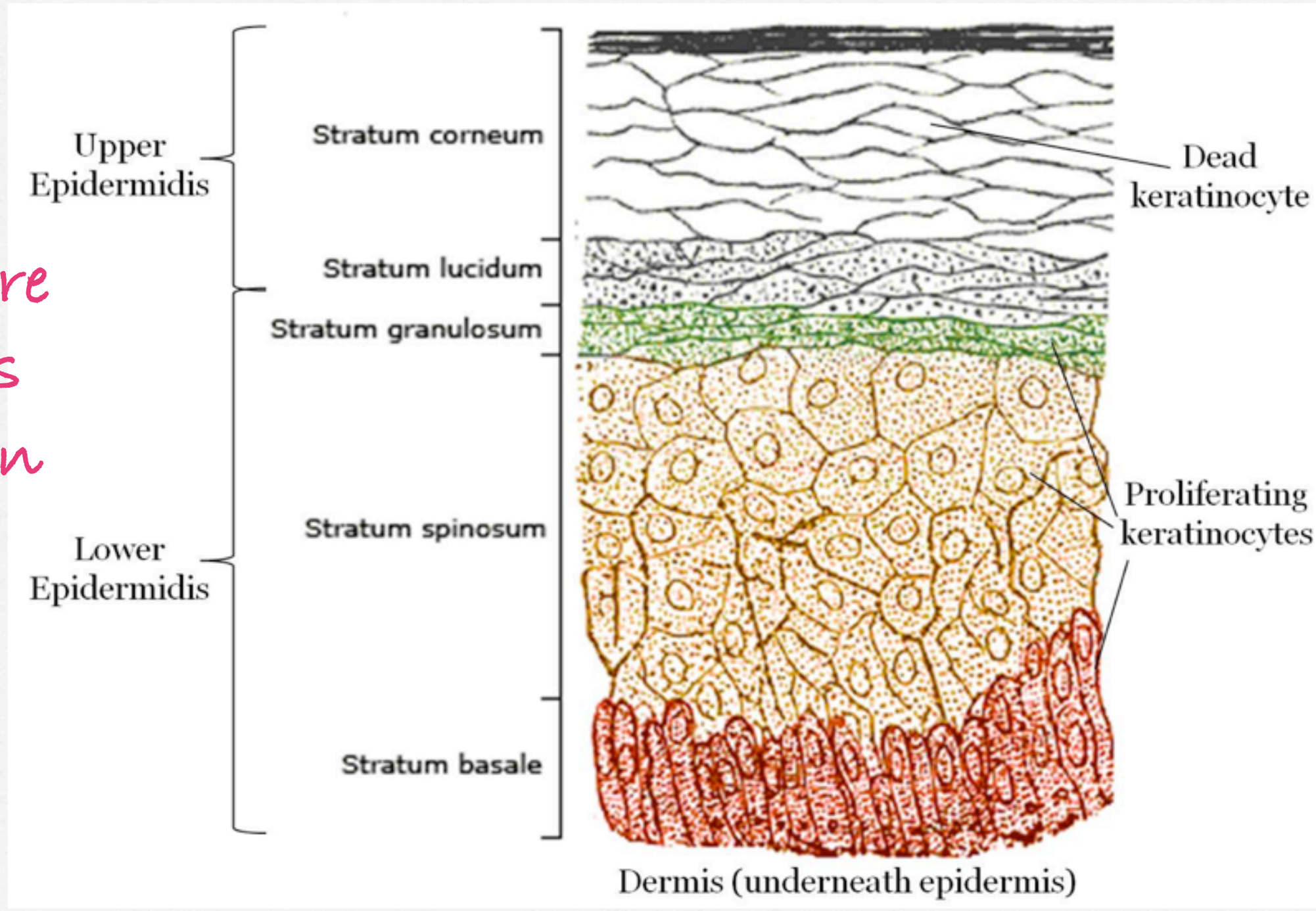
Animal Defenses against Predators

- **Skin**
- The skin is largest organ of the body.
- The skin provides protection against physical and chemical threats.
- The skin wraps around the body and protects vital organs and cells.
- The skin is composed of multiple layers of thin cells that provide thickness and better ability to protect.
- **Mucous**
- Where skin is thin animals may coat the surface with mucous to supplement the skin's protection
- This mucous can helps to trap irritants and pathogens

An Important AP Theme

- **Skin**

Structure Dictates Function



Animal Defenses against Predators

- **<u>Scales & Armor</u>**
- Scales vary in size, shape and structure.
  - Some consist of bone, enamel, minerals or collagen.
- Reptile and fish scales have slight differences but we will not distinguish between them.
  - It is interesting to note that the genes in mammals responsible for hair and teeth are same responsible for scales in fish and reptiles.
- Modified scales- *Scutes*; raised scales in herring, *Spines*; porcupine fish and stingrays, *Teeth Scales;* of the sawfish, *Blade-like scales*; of the surgeonfish, *Bony Plates*; of the stickleback and *Deciduous Scales* of anchovies easily break off to avoid predation

Animal Defenses against Predators

- **<u>Hair, Fur & Feathers</u>**
- Thick fur and hair can not only protect from the animal from cold but it protects the animal from the claws and teeth of predators.
- Some fur is modified into spines like that of the porcupine.
- Also in some animals it is the hair, fur or feathers that are responsible for the camouflage of animals
  - In fact the Shar Pei dog was bred to have rolls of fat and spiny hair that protected vital organs during dog fights.

Animal Defenses against Predators

- **CAMOUFLAGE & HIDING**
- **Animal's can hide in places where predators can not go or see.**
- **Animal's can also hide out in the open by employing camouflage.**
  - Blending is the most effective approach
  - The colors are a result of different pigments
  - Sometimes animals mimic structures in the environment like twigs or coral.

Animal Defenses against Predators

- **Types of Camouflage:**
  - *Solid Colors* for solid backgrounds
  - *Colored patterns* to match background
  - *Counter-shading* dark upper bodies and light lower bodies
    - when light hits dark color animal appears lighter, when light hits light area animal appears darker
    - this works well with fish, when looking up into the sun its harder to a fish with a white belly
  - *Copy-cats* involve shape, behavior or looking like something else that is common in the environment.

Amazing Camouflage

Animal Defenses against Predators

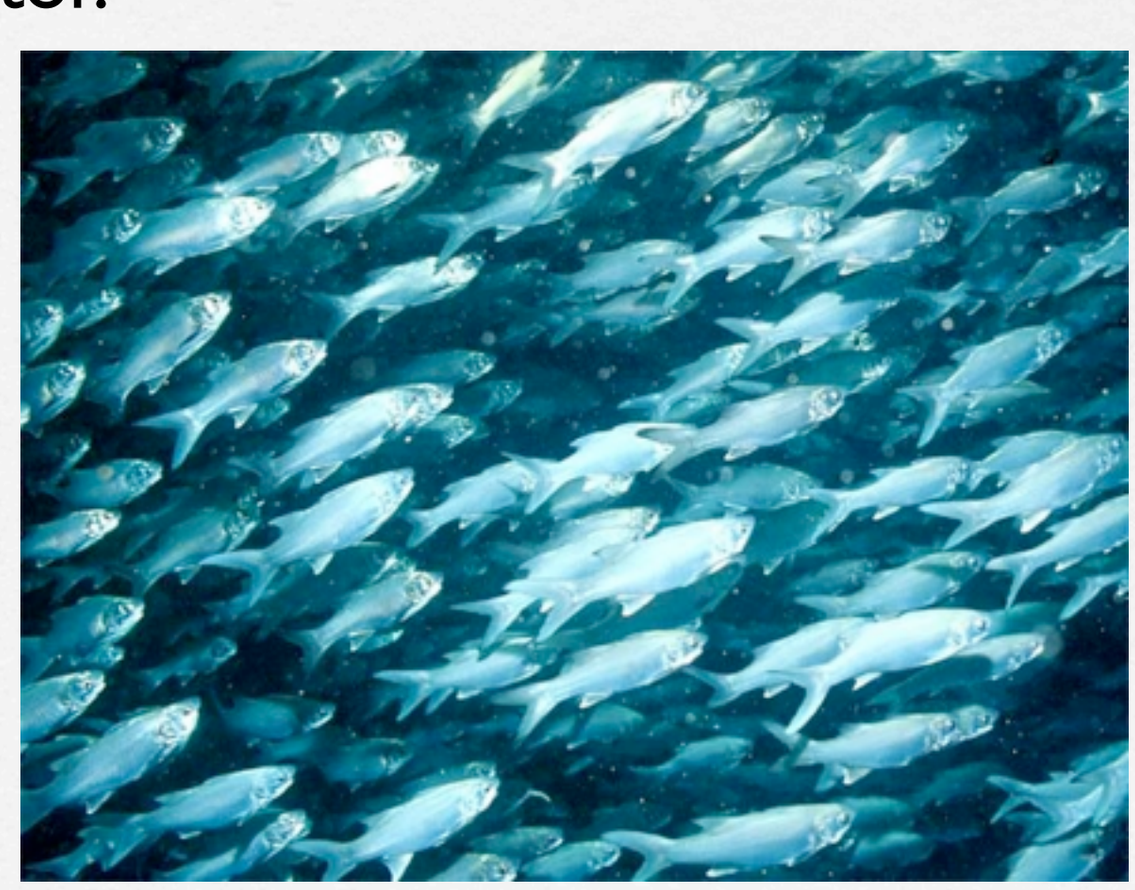
- **FIGHTING BACK!**
- **Some animals are able to deter predation by presenting the predator with a formidable challenge or danger that the predator may decide to avoid.**
- **The fight may come to the predator in the form a chemical or physical defense.**
  - The most chemical defenses include poisons/toxins that can be delivered in a number of different ways.
  - Physical defenses may include horns, antlers, spines, quills, tusks and claws.
  - Some prey travel in groups and mob the attacker

Animal Defenses against Predators

- **INTIMIDATION**
- **Some animals warn predators by visual displays**
  - Colorful reptiles and amphibians warning signs that they are poisonous to predators.

Animal Defenses against Predators

- **SAFETY in NUMBERS**
- **Some animals travel in herds or schools.**
  - This strategy lessens the chances of any one individual being picked and eaten by the predator.



Animal Defenses against Predators

- **BEHAVIOR**
- **Some behaviors are innate.**
- **Some behaviors are learned.**
  - avoiding habitats where predators are found
    - ex. Anolis lizard become arboreal with ground predators
  - being active at different times of the day than the predators
  - inflating bodies or some physical act that conveys a larger size or greater fitness to the predator
    - ex. lizards due push-ups and gazelles stot

Animal Defenses against Predators

- **BEHAVIOR**
- **Some behaviors are learned.**
  - altering activities due to threat
    - *ex. decorator crabs cover themselves with leaves and debris*
    - *walking stick insects move like twigs in the wind*
  - play dead since most predators due want carrion
    - *ex. opossum plays dead when threatened*
  - some animals use alarm calls to warn fellow prey
    - *ex. dwarf mongoose stand up and look for birds of prey while others forage for food*

Crazy Animal Defenses

(Image via **salamandarcandy**)

The **horned lizard** is a seemingly normal looking lizard found in the southwest region of the United States. It doesn't use its horns to defend itself, as you might expect. Rather, when attacked, it pressures its own sinus cavities until the blood vessels in its eyes burst, and it sprays its attacker with blood from its eyes.

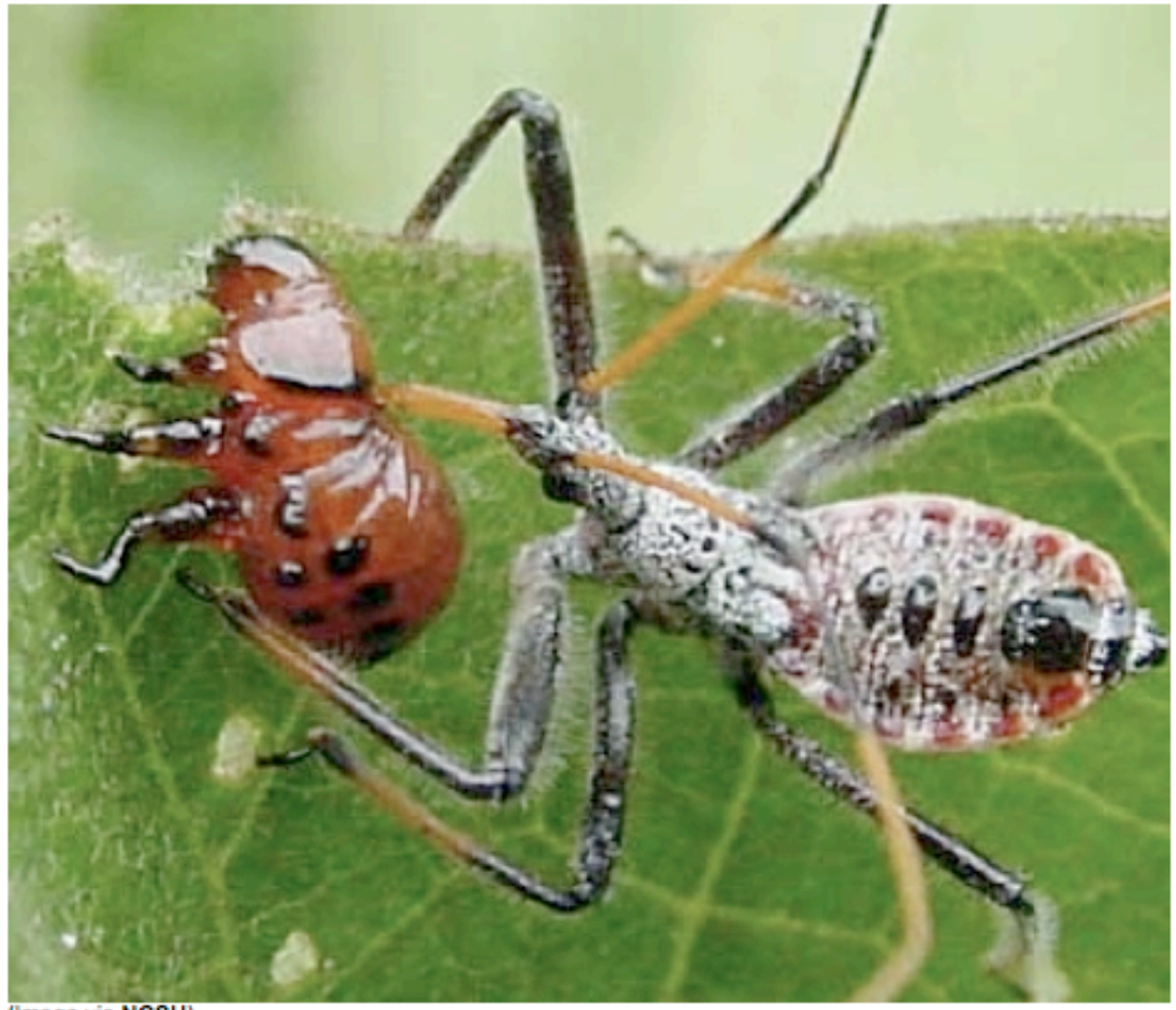
(Images via **Canterbury**)

Oh, there's nothing like a pulsating jet of foul boiling anal fluid to say "Howdy, neighbor!" The **bombardier beetle** may look innocent enough, but it is famous for being able to spray boiling hot and chemically toxic bodily fluids in the direction of any would-be predator. The bombardier beetle doesn't exactly melt in your mouth (but it will melt you).

Crazy Animal Defenses

(Image via **cafeguaguau**)

You know **Malaysian ants** – always exploding all over themselves, ruining the fun. All kidding aside, it's really true. Malaysian ants internally combust under threat, causing their bodies to explode (they wait until their enemies are close enough to die before detonating). *Camponotus saundersi* soldier ants have large glands full of poison inside their bodies. When they sense a threat, they contract their abs, causing the glands on either side of their bodies to explode and spray poison.



(Image via **NCSU**)

Like our little friend the **komodo dragon**, potato beetle babies (larvae) cover themselves in their own poop to avoid being eaten. Unlike baby komodos, the **potato beetle's feces** are actually poisonous to predators. Smelly but effective!

Crazy Animal Defenses

(Image via **Illinois Dept. of Natural Resources**)

The skunk, or polecat, is actually an attractive little mammal and some people keep them as pets (sans glands, of course). **Skunks** are omnivores but will turn to trash and carrion when no fresh insects or honeybees, their favorite food, are available. Though their amazing musk can be smelled miles away, their vision is exceptionally weak, and most skunks can only see about 10 feet in front of them. As a result, many are run over – half of all skunk deaths, in fact, are due to humans. All Mustelidae family members (like weasels and ferrets) can spray musk, but skunks are famously the most potent. The skunk's anal musk is so powerful that if sprayed directly, the victim will experience temporary blindness.

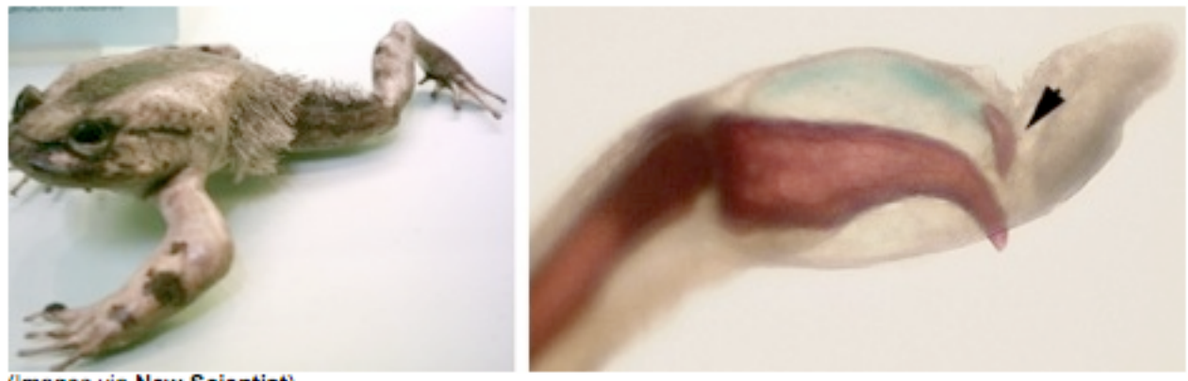
(Images via **reefseekers** and **alaskaunderseatours**)

The sea cucumber can literally take on different body states – from hard to liquid – in order to defend itself. From **wikipedia**: "Like other **echinoderms** the cuke has a type of **collagen** in its skin capable of excreting or absorbing more water effectively changing from a 'liquid' to a 'solid.' They can turn their bodies into mush, climb through small cracks and then solidify into small lumps so that they cannot be extracted." Even more amazing than effectively scattering yourself into pieces of your collective whole and then reassembling: the ability to turn yourself inside out so that your digestive tract's toxic juices poison your enemies. Yeah, the sea cucumber can do that, too. Do not mess.

Crazy Animal Defenses

(Image via **animalphotos**)

The cute little opossum has a number of tricks up its defensive sleeve. It can play dead. It can foam at the mouth in an attempt to convince its predators that it is toxic, sick or perhaps just bat sh*t insane. It can also emit a green anal fluid that smells nearly as bad as a skunk's offensive spray (though mercifully it can easily be washed off). **Opossums playing dead** actually slip into a semi-comatose state, thus removing any excitement of the kill for a predator.



(Images via **New Scientist**)

The hairy frog or "horror frog" intentionally breaks its own bones to turn out a wicked set of cat-like claws. Like Wolverwine, only slimy and a lot more terrifying because *it's a freaking frog*. Scientists don't know if the claw is able to retract once it pierces through the skin. According to **New Scientist**: "*Trichobatrachus robustus* actively breaks its own bones to produce claws that puncture their way out of the frog's toe pads, probably when it is threatened." Also, it is apparently hairy. This doesn't stop Cameroon locals from spearing and roasting hairy frogs as a tasty snack.

Top 10 most odd mammal defenses go to- http://listverse.com/2010/05/18/top-10-mammals-with-odd-defense-mechanisms/

To see top 10 most bizarre bird defenses go to- http://listverse.com/2010/12/23/10-birds-with-truly-odd-defenses/

Animal Defenses against Pathogens

Now we will explore the fight against the smallest invaders whose threat can be just as great as larger predator.

- The animal strategy against bacteria, viruses and parasites has two goals.
- First goal: Do not let the pathogen in the body or cell(s).
- Second goal: Should the pathogen "get in" then the animal must find, recognize and destroy it before it inflicts it damage.

Animal Defenses against Pathogens

Note: Vertebrate defense mechanisms are so similar to invertebrates that we study the human model and apply the concepts and mechanisms to all other animals.

- First goal: Do not let the pathogen in the body or cell(s).
  - *This is accomplished through the Integumentary, Lymphatic & Immune Systems*
  - *This immunity is called innate immunity or non-specific defenses.*
- Second goal: Should the pathogen "get in" then the animal must find, recognize and destroy it before it inflicts it damage.
  - *This is accomplished through the Immune System.*
  - *This immunity is called acquired immunity or specific defenses.*

Animal Defenses against Pathogens

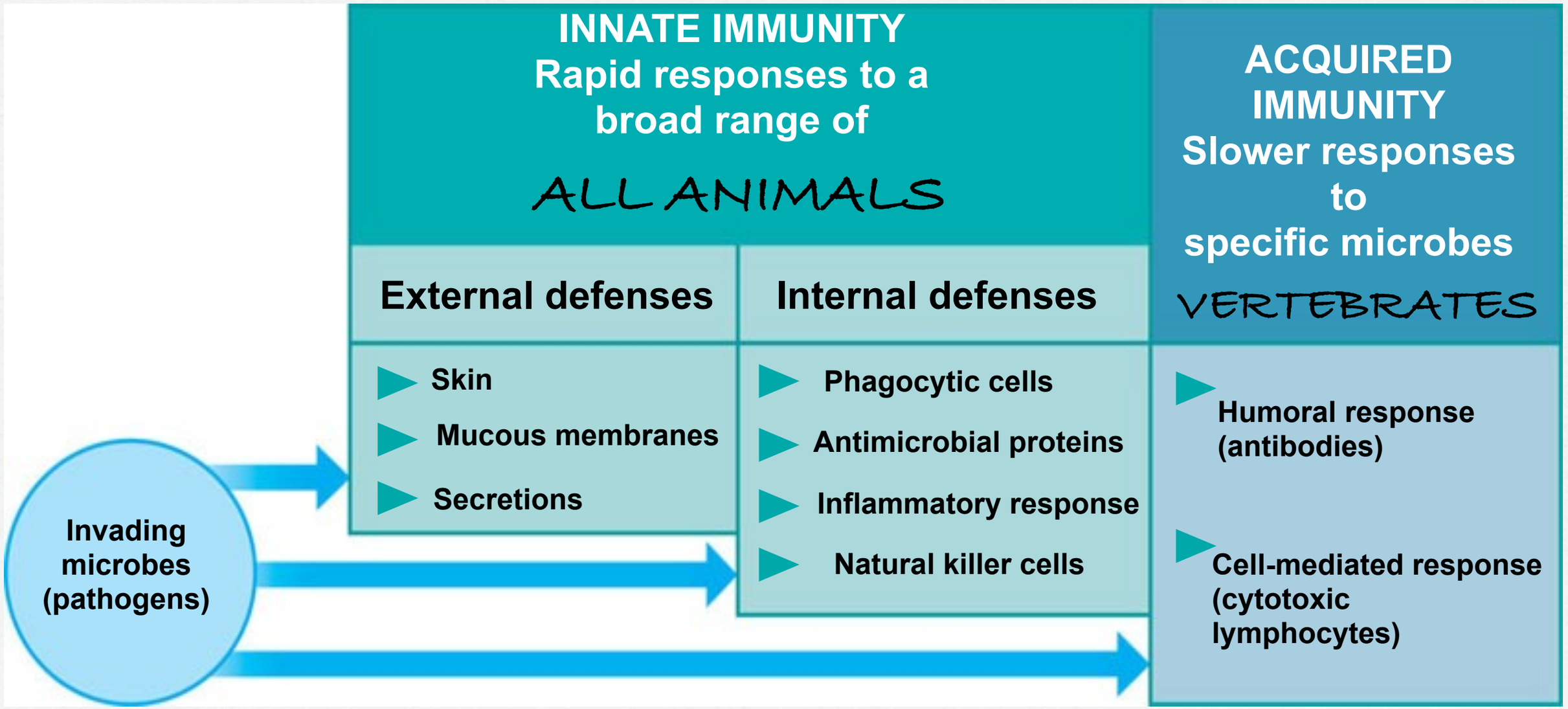
Why do you suppose pathogens "want in"?
Why do they infect multicellular organisms?

Multicellular organisms have worked hard to provide an ideal environment for the cells that make up the organism; they are protected, they are fed, they wastes are eliminated etc and the pathogens are looking for a free ride!

Animal Defenses against Pathogens

Always present even before exposure to pathogen etc.

Develops after exposure to pathogen etc.



Animal Defenses against Pathogens

Non-Specific External Defenses. (PHYSICAL BARRIERS)

- SKIN: physical barrier against microbes etc.
    - *multiple layers of flat skin cells provide increased protection*
- MUCOUS MEMBRANES: produce a viscous fluid that traps microbes
    - *much of this mucous ends up in the stomach a very inhospitable place*
- RESIDENT BACTERIA: prevents the attachment of foreign microbes

Animal Defenses against Pathogens

Non-Specific External Defenses. (CHEMICAL BARRIERS)

- SECRETIONS: create a hostile environment against microbes
  - *create a skin pH of 3-5 and it also contains lysozyme an enzyme that digests the cell wall of many bacteria*
  - *salts, fatty acids of skin inhibit microbial growth,*
  - *ANTIMICROBIAL AGENTS: generate lysozymes that punch holes into the bacteria thus killing them*

Can vomiting and diarrhea be considered innate immunity? Why? or Why Not?

Yes…Both indiscriminately purge harmful agents

Animal Defenses against Pathogens

Non-Specific <u>Internal</u> Defenses.

- All internal defenses requires the identification of "self" and "non-self"
- This "self" and "non-self" identification requires *molecular recognition.*
    - *where receptor molecules bind to specific molecules that are foreign or molecules that are part of foreign cells*

Animal Defenses against Pathogens

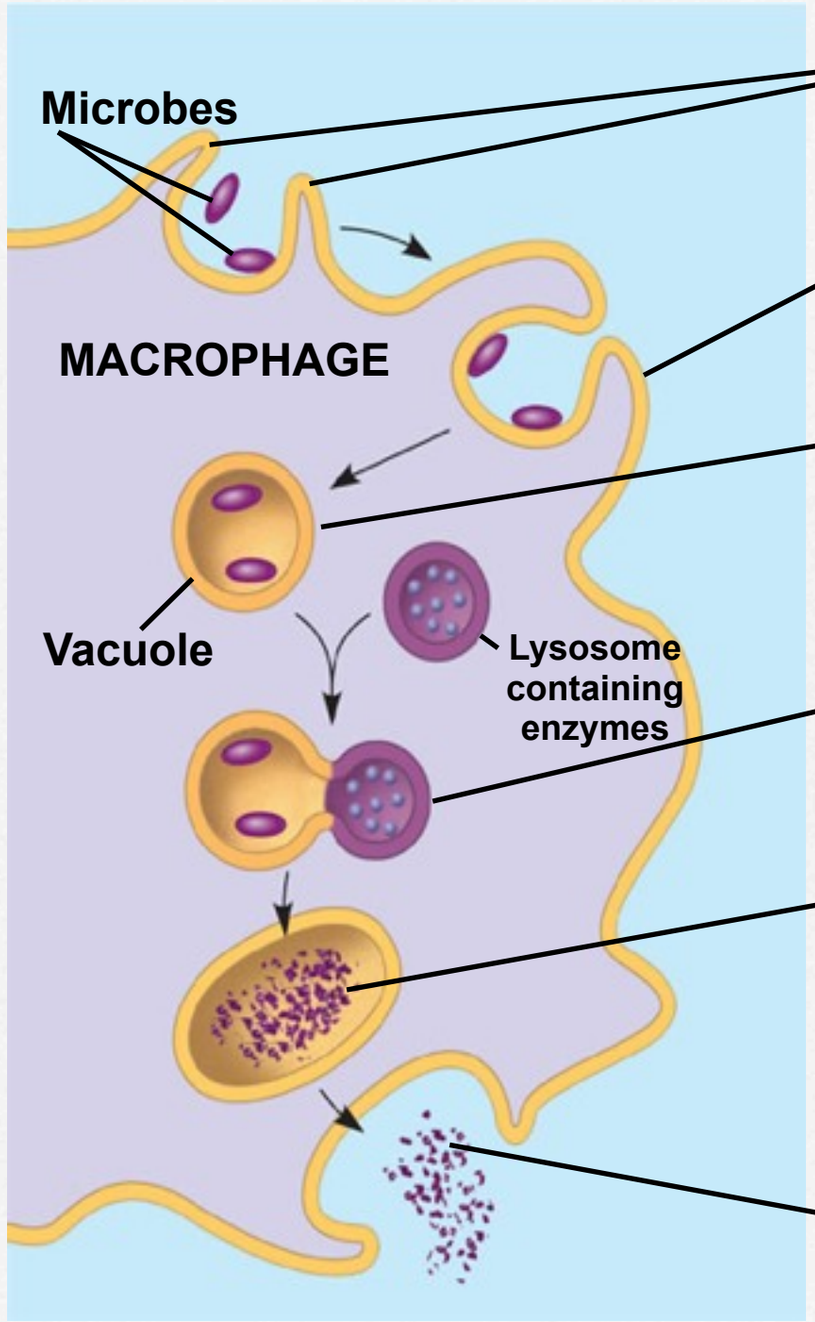
Non-Specific Internal Defenses. (CHEMICAL AGENTS)

- INTERFERONS: *provide innate protection against viruses and activate macrophages*
- HISTAMINES: increased capillary permeability with *increased blood flow brings more white blood cells to area of infection.*
- *PYROGENS: induce fever that inhibits pathogen reproduction*

Animal Defenses against Pathogens

Non-Specific External Defenses. (PHAGOCYTOSIS)

- PHAGOCYTES: white blood cells
  - *ingest invading microbes & initiate the inflammatory response*
- MACROPHAGES: a specific type of phagocyte can be found migrating through the body



Animal Defenses against Pathogens

Non-Specific Internal Defenses. (FURTHER DEFENSES)

- EOSINOPHILS & DENDRITIC CELLS: eosinophils defe*nd against multicellular invaders like parasitic worms*
- NATURAL KILLER CELLS: *patrol body looking for cells that are infected with viruses.*
  - *when an infected cell(s) is found they trigger apoptosis (cellular suicide) to prevent the spread of infection*
- COMPLEMENT SYSTEM: *a group of 30 or so proteins that lyse invading cells, recruit white blood cells and help to activate the inflammatory response*

Animal Defenses against Pathogens

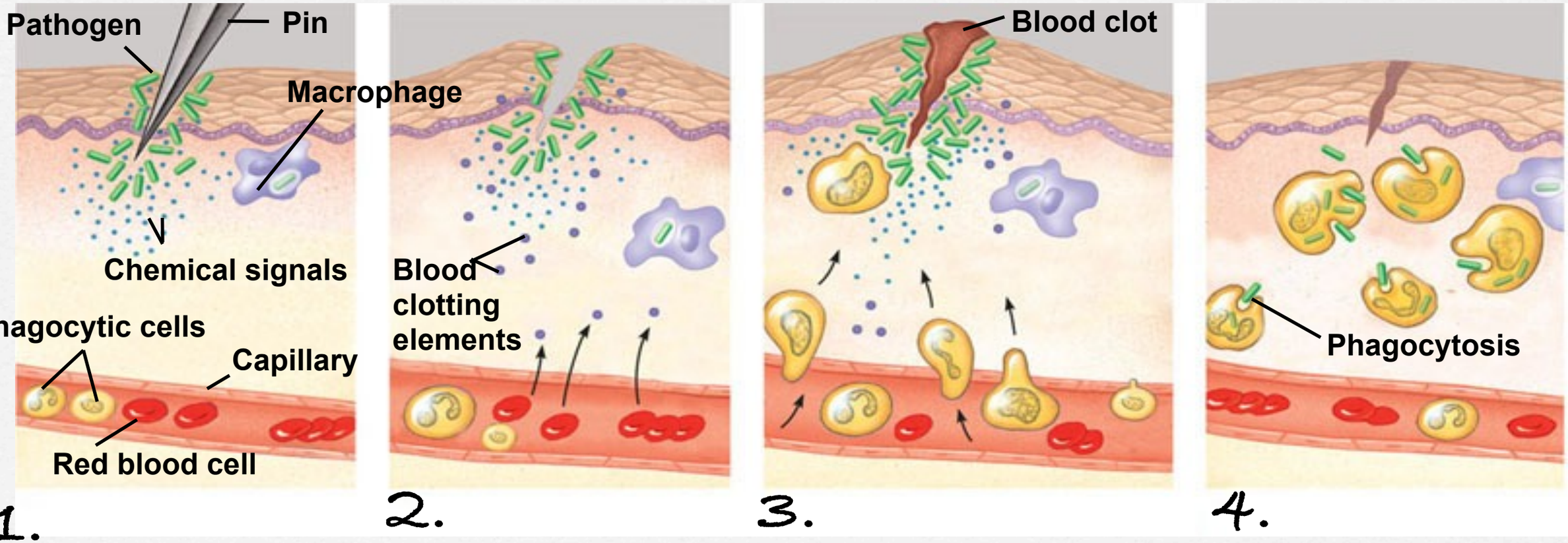
Non-Specific Internal Defenses. (INFLAMMATION)

- INFLAMMATORY RESPONSE: *dilates blood vessels that allow more fluid, phagocytes and antimicrobial proteins to enter the tissues at the site of infection.*

- *the response is trigger by the release of histamines and other chemicals from the injured cells*

Animal Defenses against Pathogens

Inflammation



1. Chemical signals released by activated macrophages and mast cells at the injury site cause nearby capillaries to widen and become more permeable.

2. Fluid, antimicrobial proteins, and clotting elements move from the blood to the site. Clotting begins.

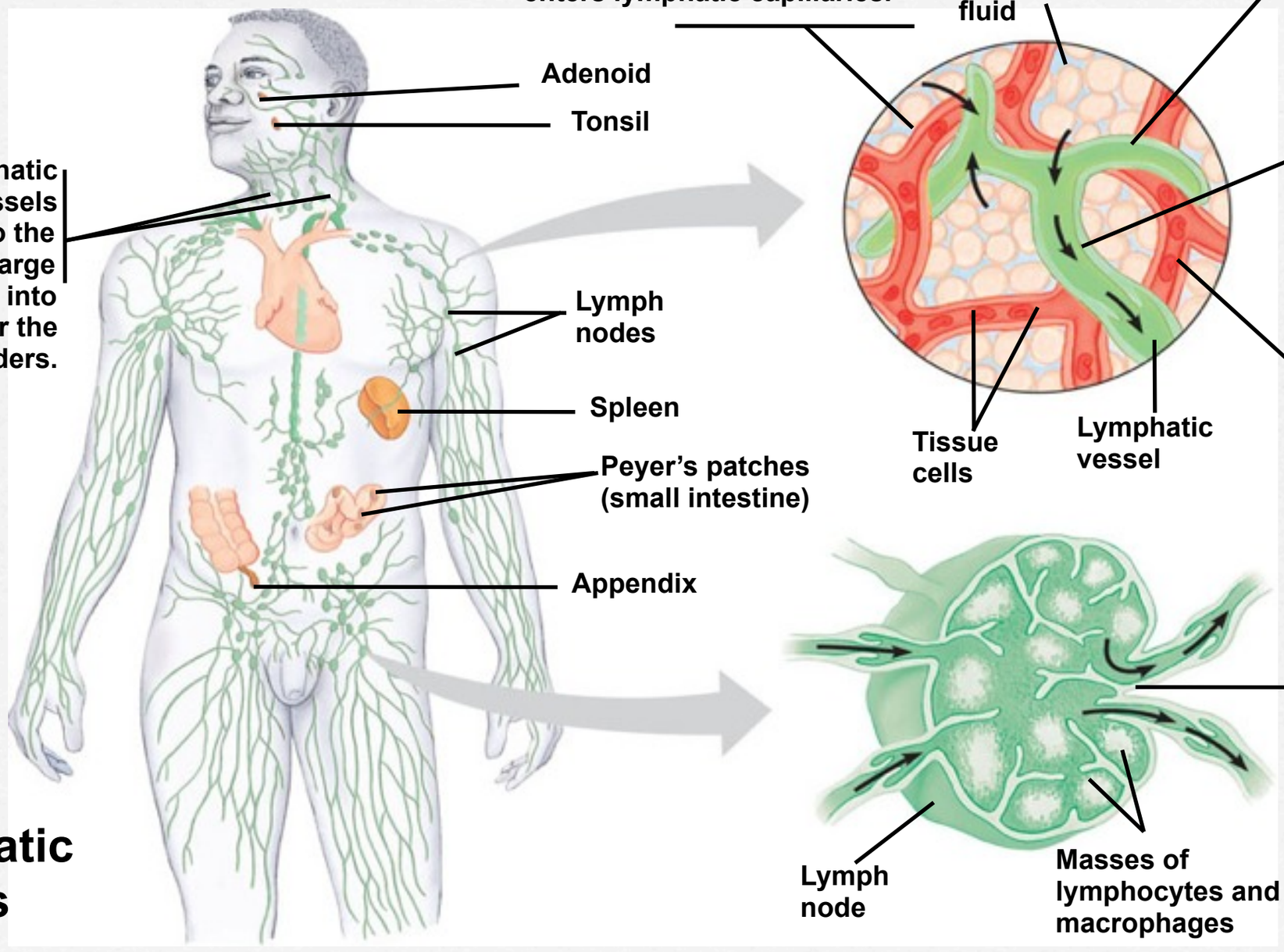
3. Chemokines released by various kinds of cells attract more phagocytic cells from the blood to the injury site.

4. Neutrophils and macrophages phagocytose pathogens and cell debris at the site, and the tissue heals.

Animal Defenses against Pathogens

Lymphatic System Plays an important role in defense as well.

1. Interstitial fluid bathing the tissues, along with the white blood cells in it, continually enters lymphatic capillaries.



4. Lymphatic vessels return lymph to the blood via two large ducts that drain into veins near the shoulders.

2. Fluid inside the lymphatic capillaries, called lymph, flows through lymphatic vessels throughout

3. Within lymph nodes, microbes and foreign particles present in the circulating lymph encounter macro-phages, dendritic cells, and lymphocytes, which carry out various defensive actions.

Lymphatic vessels

Animal Defenses against Pathogens

<u>Specific</u> Internal Defenses.

- ACQUIRED or ADAPTIVE IMMUNITY: 4 Characteristics
  - 1. Immense diversity- of lymphocytes & receptors (millions)
  - 2. Self Tolerant- should not attack own cells
  - 3. Proliferation- activation of immune response creates many more T cells and B cells
  - 4. Immunological Memory- stronger and more rapid response to a previously encountered antigen

Animal Defenses against Pathogens

<u>Specific</u> Internal Defenses.

- ACQUIRED or ADAPTIVE IMMUNITY: lymphocytes provide ***specific*** defenses against infection.
    - it is the bodies second line of defense
    - it again involves lymphocytes
        - (general=white blood cells) (specifically T cells and B cells)
    - it looks for and recognizes ***antigens***

Adaptive immunity is found only in vertebrates

Animal Defenses against Pathogens

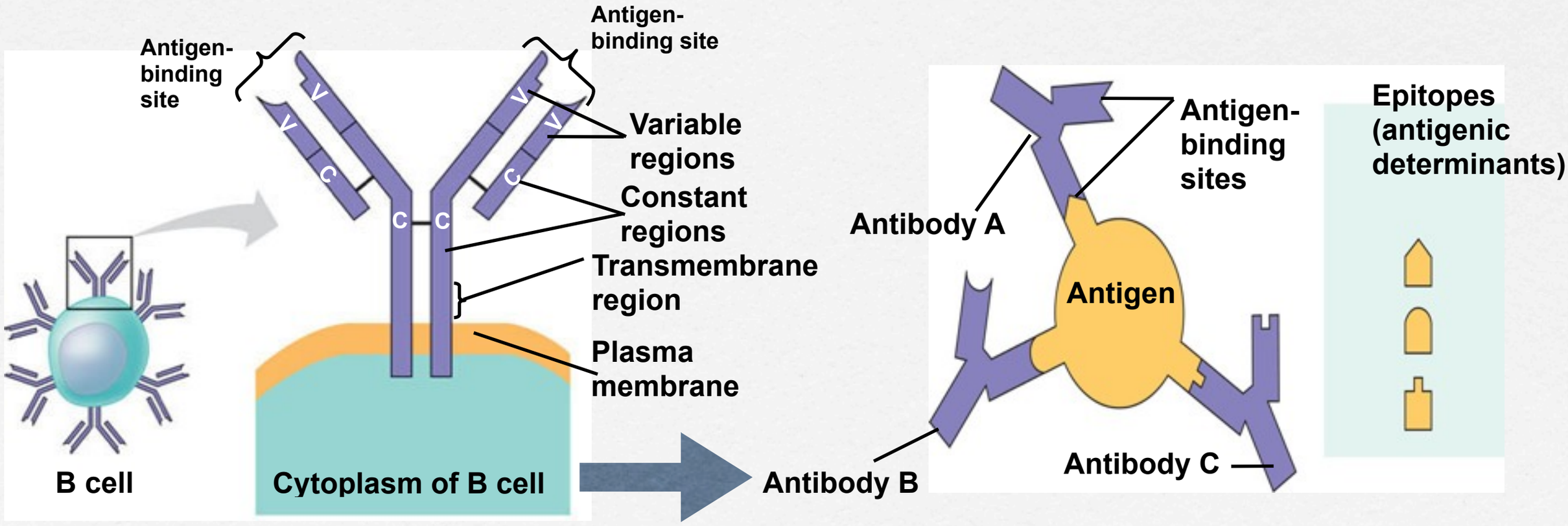
Antigens

- An antigen is foreign molecule that is recognized by T cells and B cells as "not self"
- The lymphocytes recognize and bind to antigens by the "shape" of the antigen

Animal Defenses against Pathogens

B Cells

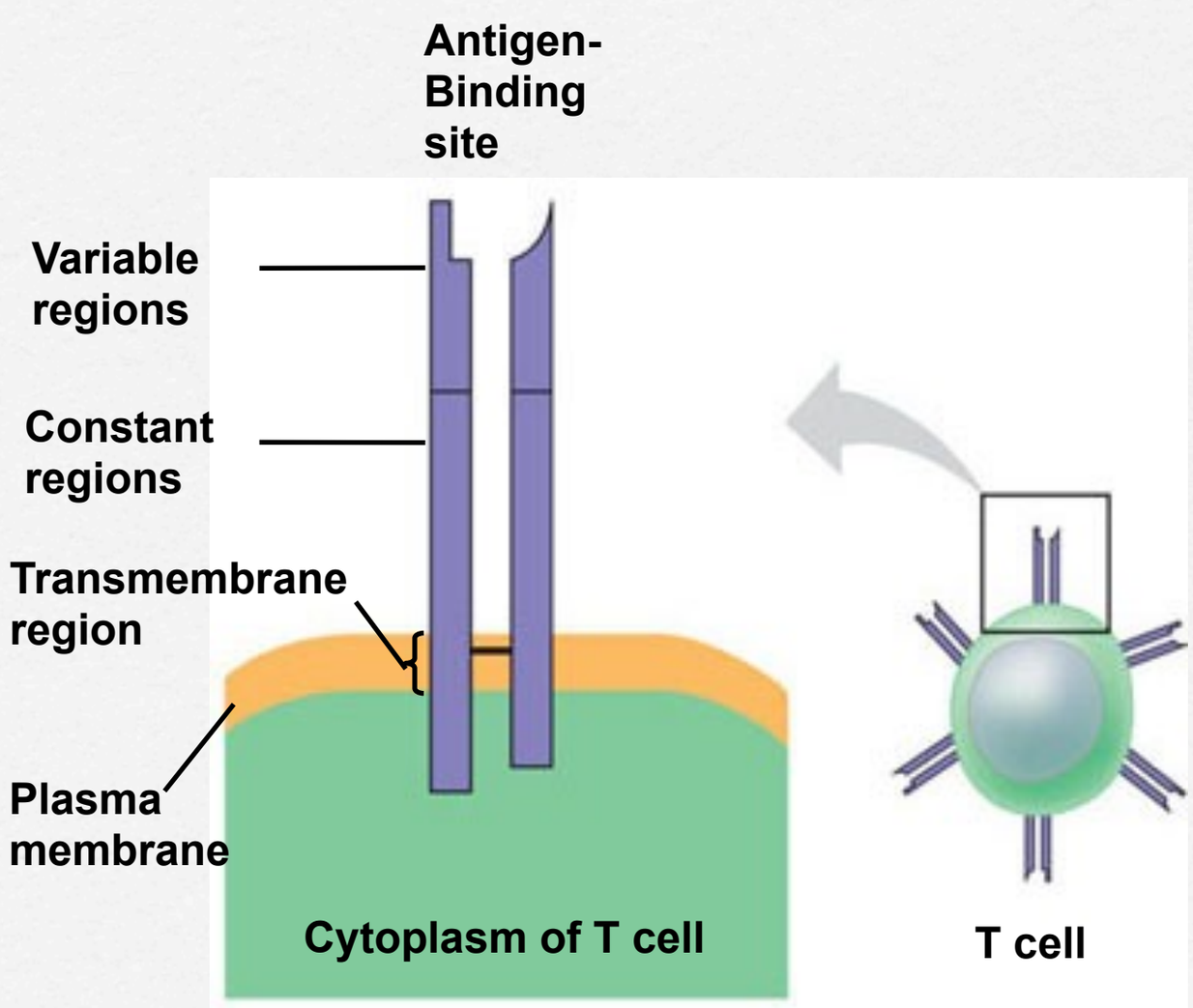
- B cells bind to epitopes of "whole" or "intact" antigens that are circulating in body fluids
- Once B cells recognize the antigen, they produce and secrete antibodies that identically shaped to B cell antigen receptors



Animal Defenses against Pathogens

T Cells

- T cells bind only to fragments of antigens that are displayed on the surface of host cells
- The antigen presentation requires another protein called the major histocompatibility complex (MHC)

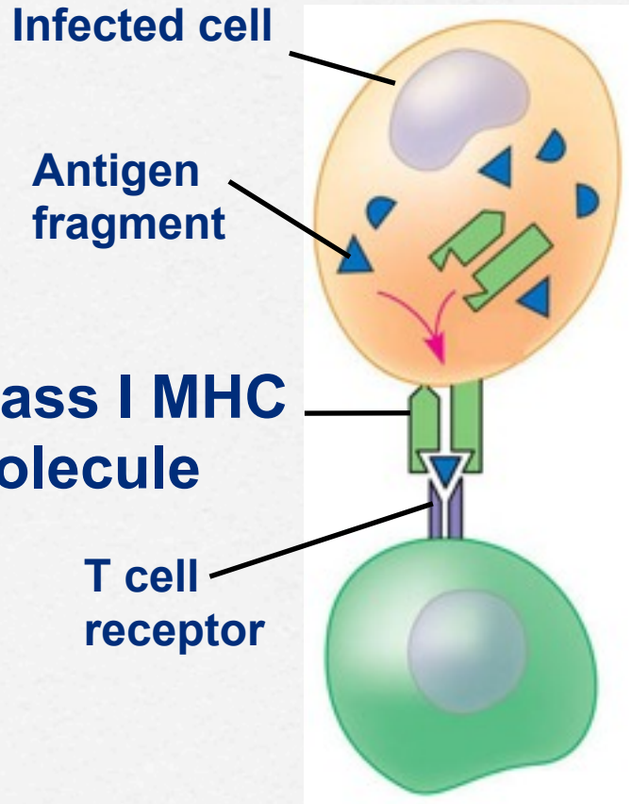


Animal Defenses against Pathogens

Antigen:

Presentation & Recognition

- Class I MHC molecules, found on almost all nucleated cells of the body.
- Display peptide antigens to cytotoxic T cells



1.

A fragment of foreign protein (antigen) inside the cell associates with an MHC molecule and is transported to the cell surface.

2.

The combination of MHC molecule and antigen is recognized by a T cell, alerting it to the infection.

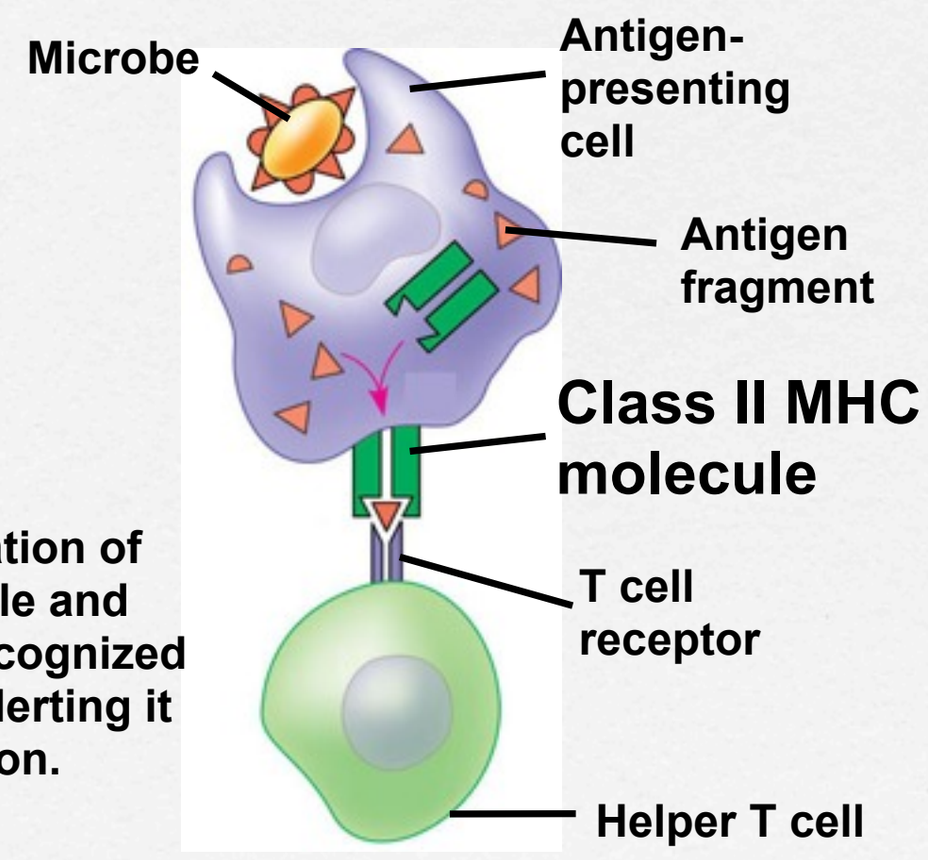
Animal Defenses against Pathogens

Antigen:

Presentation & Recognition

- Class II MHC molecules, found on dendritic cells, macrophages and B cells.
- Display peptide antigens to helper T cells

1. **A fragment of foreign protein (antigen) inside the cell associates with an MHC molecule and is transported to the cell surface.**



2. **The combination of MHC molecule and antigen is recognized by a T cell, alerting it to the infection.**

Review & Build

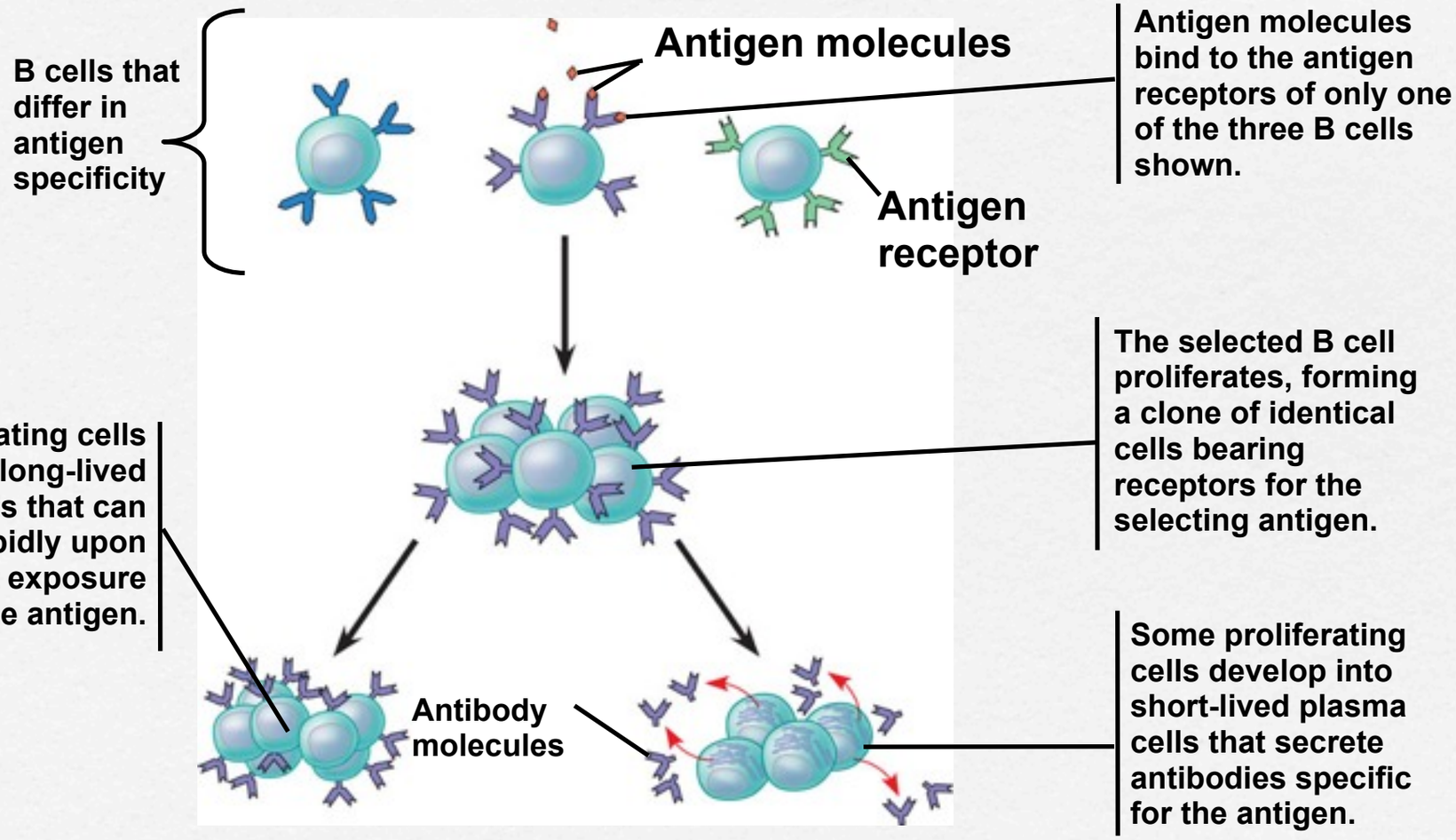
- ACQUIRED or ADAPTIVE IMMUNITY: 4 Characteristics
  - **1. Immense diversity- of lymphocytes & receptors (millions)**
    - achieved by shuffling genes around to create a thousands of different proteins later assembled to produce millions of different receptors
    - details discussed later in the year

Review & Build

- ACQUIRED or ADAPTIVE IMMUNITY: 4 Characteristics
  - **2. Self Tolerant- should not attack own cells**
    - the generation of B cell and T cell diversity is somewhat random, as a result some carry receptors its own epitopes
    - as **B cells** mature in **B**one marrow these lymphocytes carrying self epitopes are killed via apoptosis (programmed cell death)
    - as **T cells** mature in **T**hymus these lymphocytes carrying self epitopes are killed via apoptosis (programmed cell death)

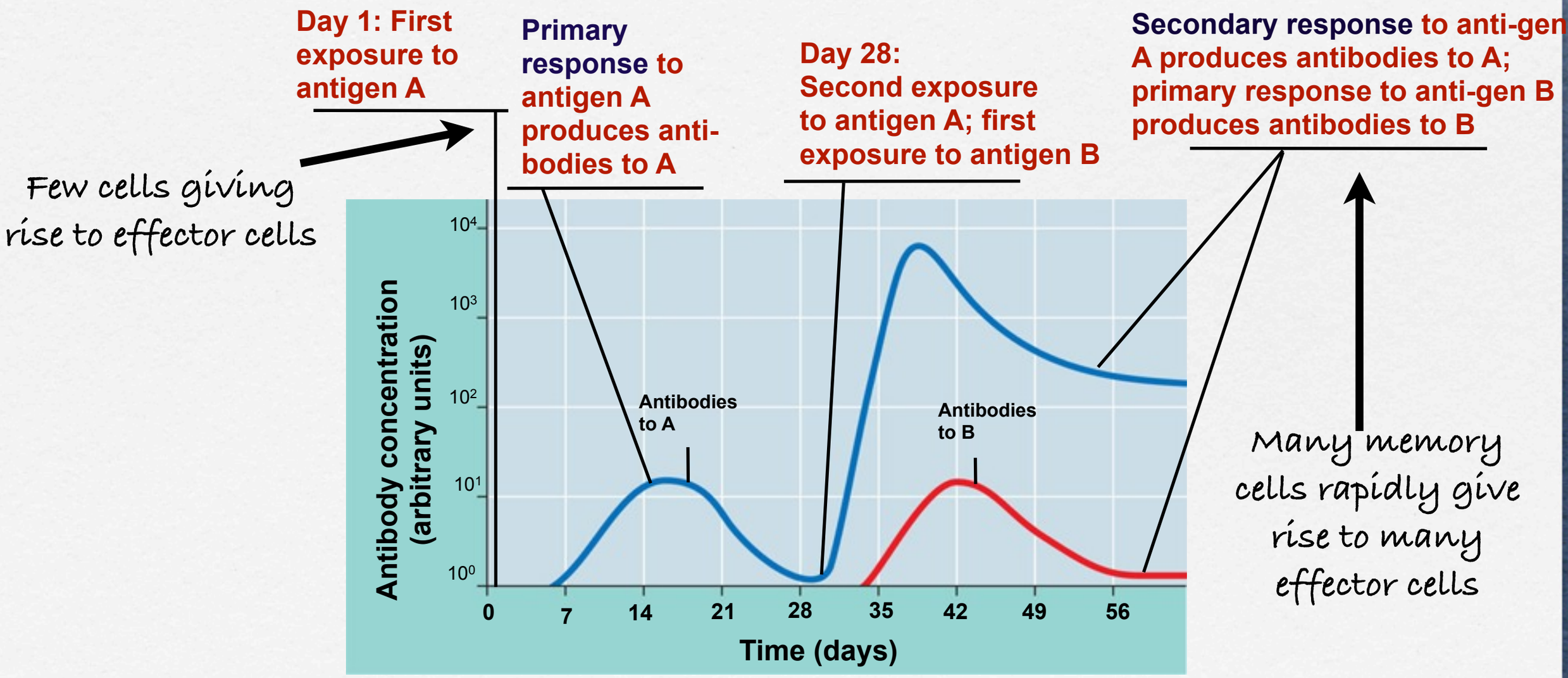
Review & Build

- ACQUIRED or ADAPTIVE IMMUNITY: 4 Characteristics
  - 3. Proliferation- activation of immune response creates many more T cells and B cells

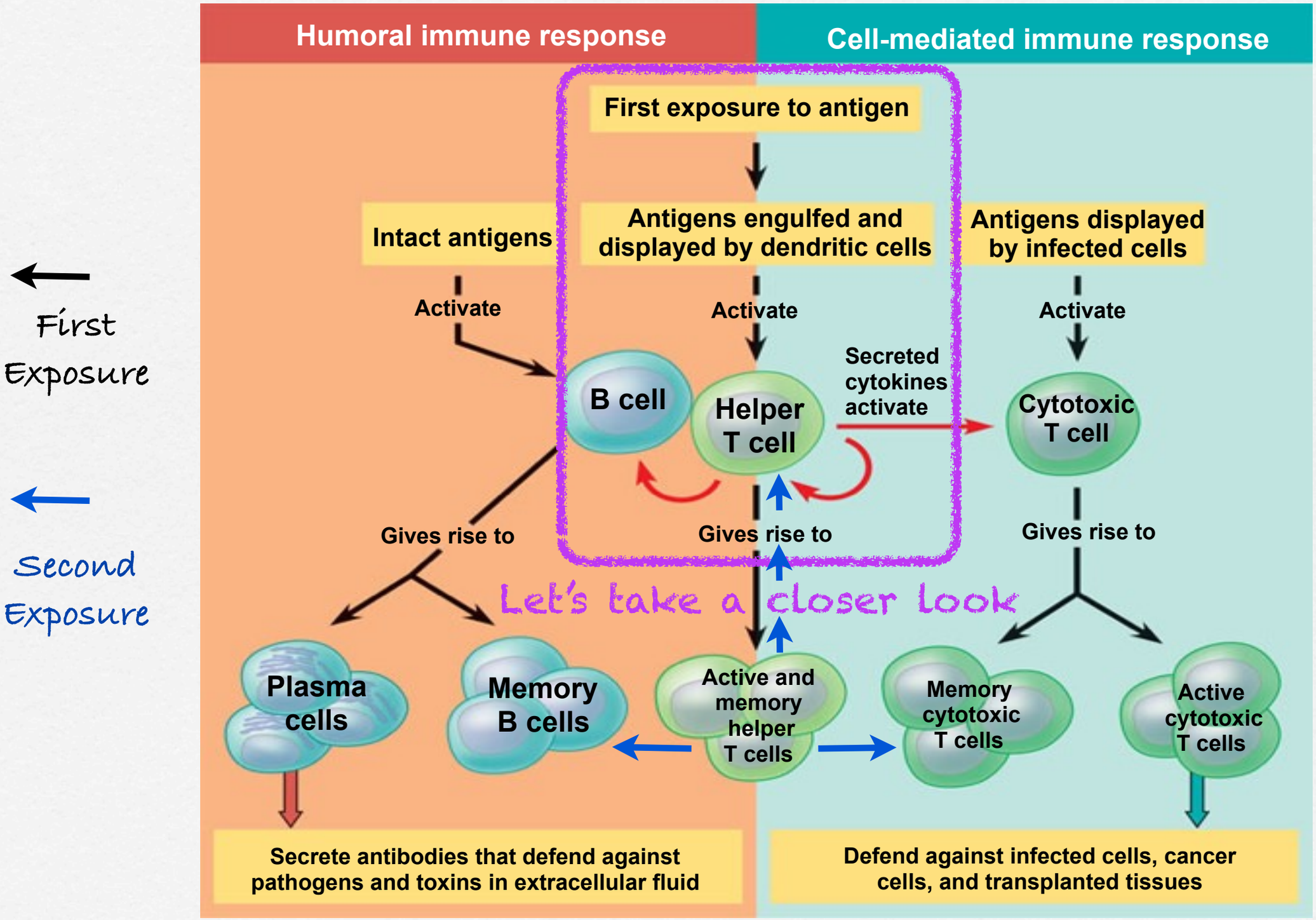


Review & Build

- ACQUIRED or ADAPTIVE IMMUNITY: 4 Characteristics
  - 4. Immunological Memory- stronger and more rapid response to a previously encountered antigen



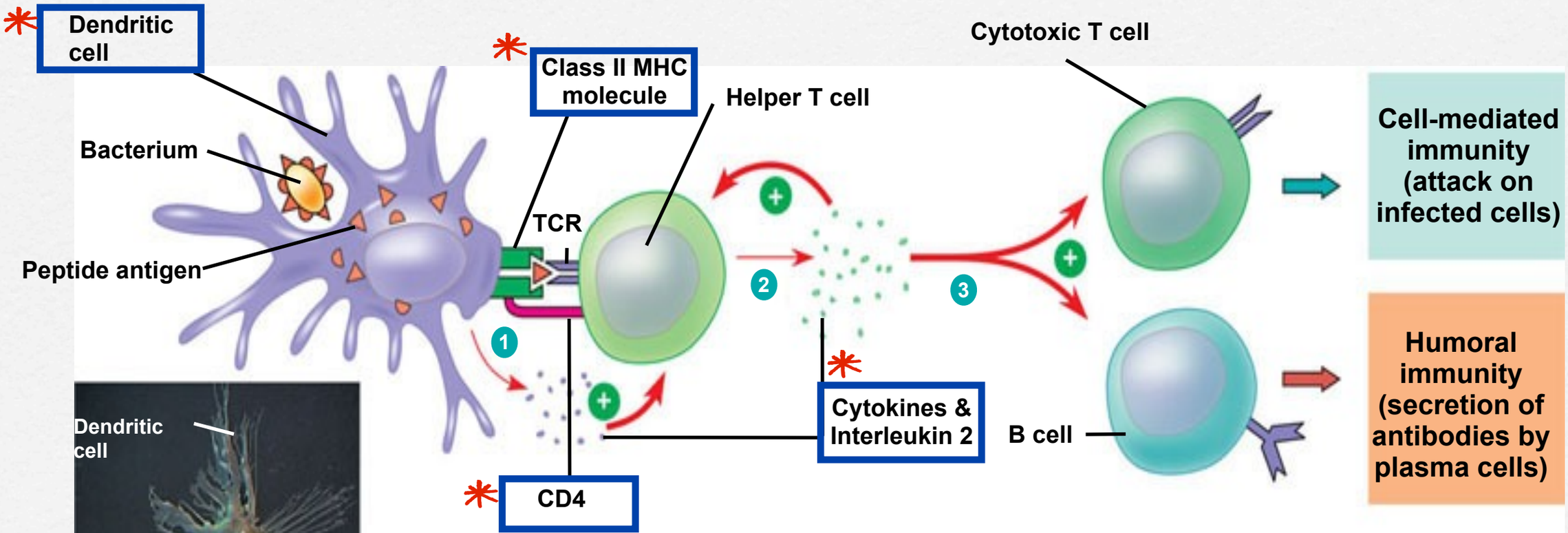
Overview Of Acquired Immunity

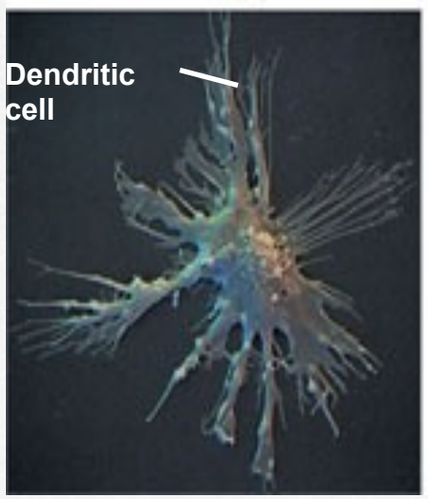


Central Role of Helper T Cells

If dendritic cell presents antigen it is likely a primary immune response

1. After a dendritic cell engulfs and degrades a bacterium, it displays bacterial antigen fragments (peptides) complexed with a class II MHC molecule on the cell surface. A specific helper T cell binds to the displayed complex via its TCR with the aid of CD4. This interaction promotes secretion of cytokines by the dendritic cell.

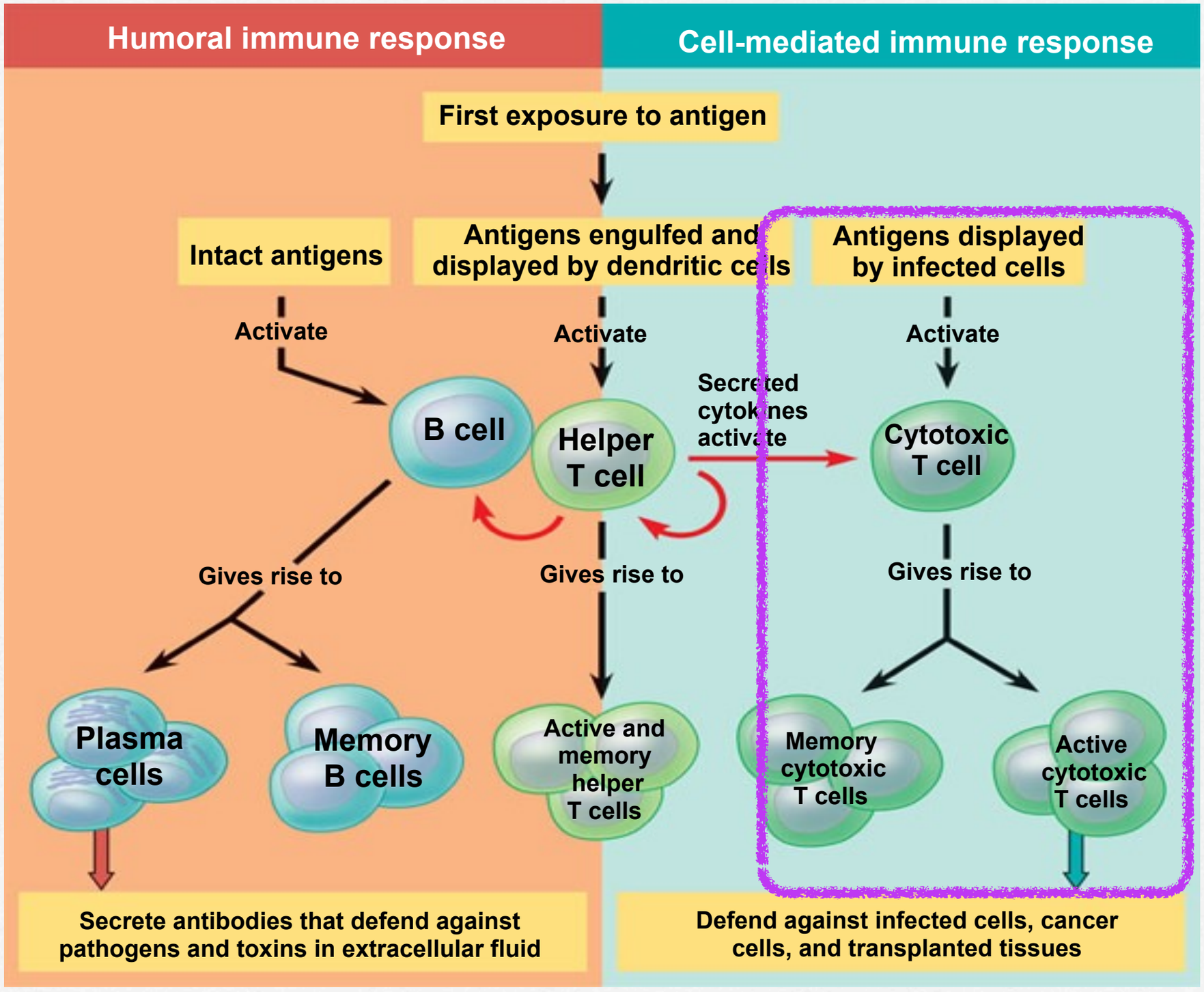




2. Proliferation of the T cell, stimulated by cytokines from both the dendritic cell and the T cell itself, gives rise to a clone of activated helper T cells (not shown), all with receptors for the same MHC–antigen complex.

3. The cells in this clone secrete other cytokines that help activate B cells and cytotoxic T cells.

Overview Of Acquired Immunity



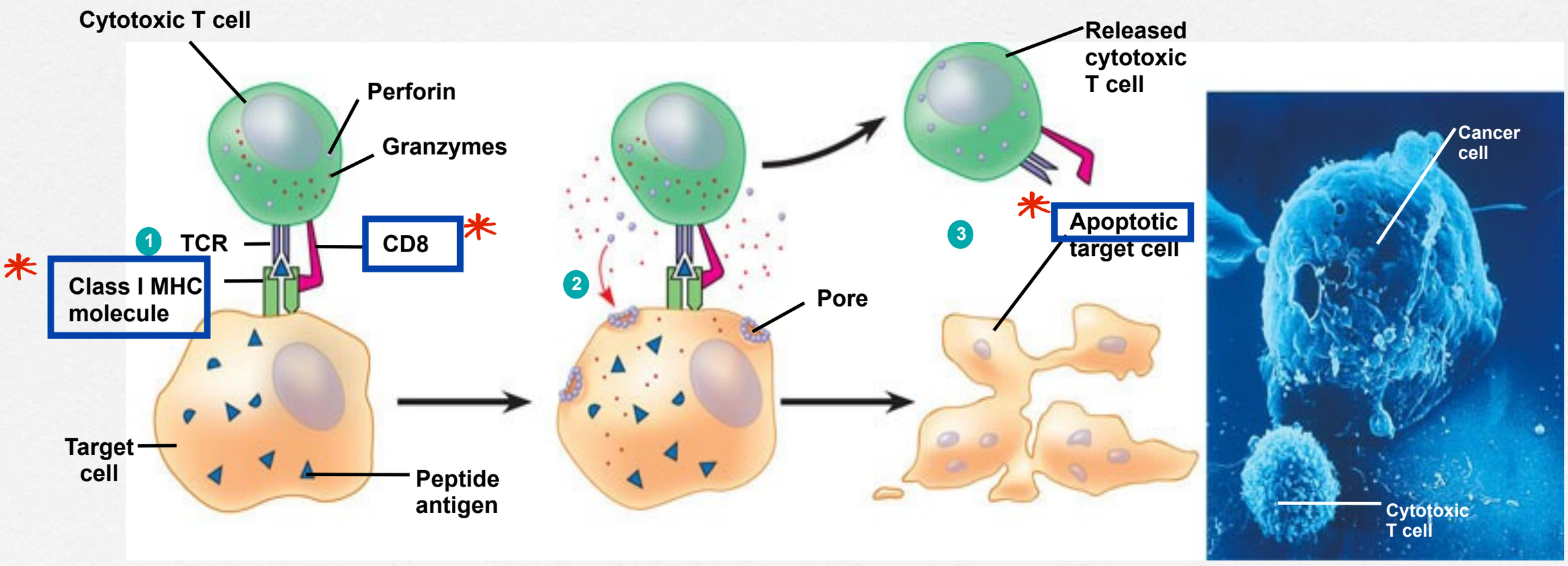
Let's take a closer look

Cytotoxic T Cells

1. A specific cytotoxic T cell binds to a class I MHC–antigen complex on a target cell via its TCR with the aid of CD8. This interaction, along with cytokines from helper T cells, leads to the activation of the cytotoxic cell.

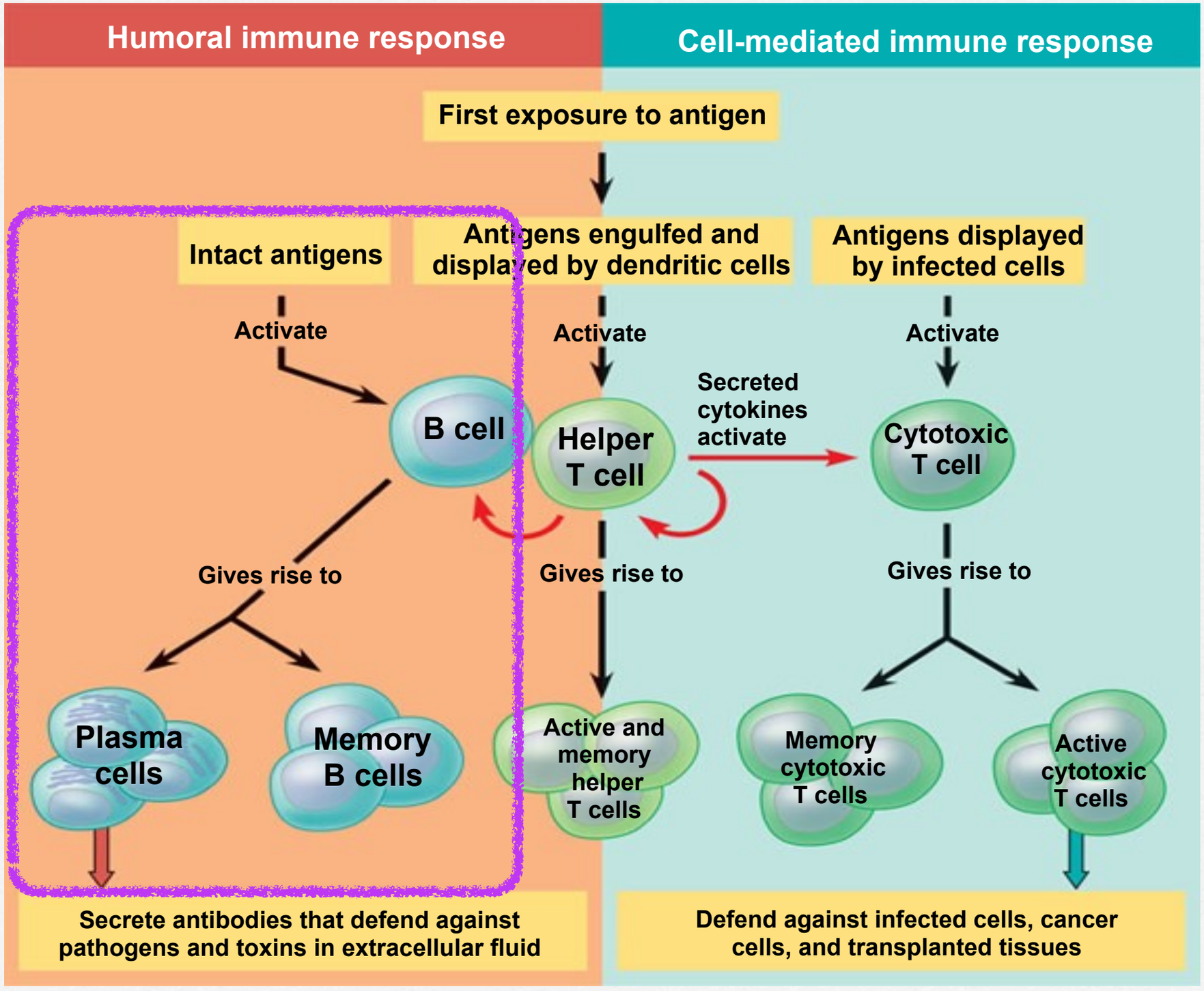
2. The activated T cell releases perforin molecules, which form pores in the target cell membrane, and proteolytic enzymes (granzymes), which enter the target cell by endocytosis.

3. The granzymes initiate apoptosis within the target cells, leading to fragmentation of the nucleus, release of small apoptotic bodies, and eventual cell death. The released cytotoxic T cell can attack other target cells.



Overview Of Acquired Immunity

Let's take a closer look

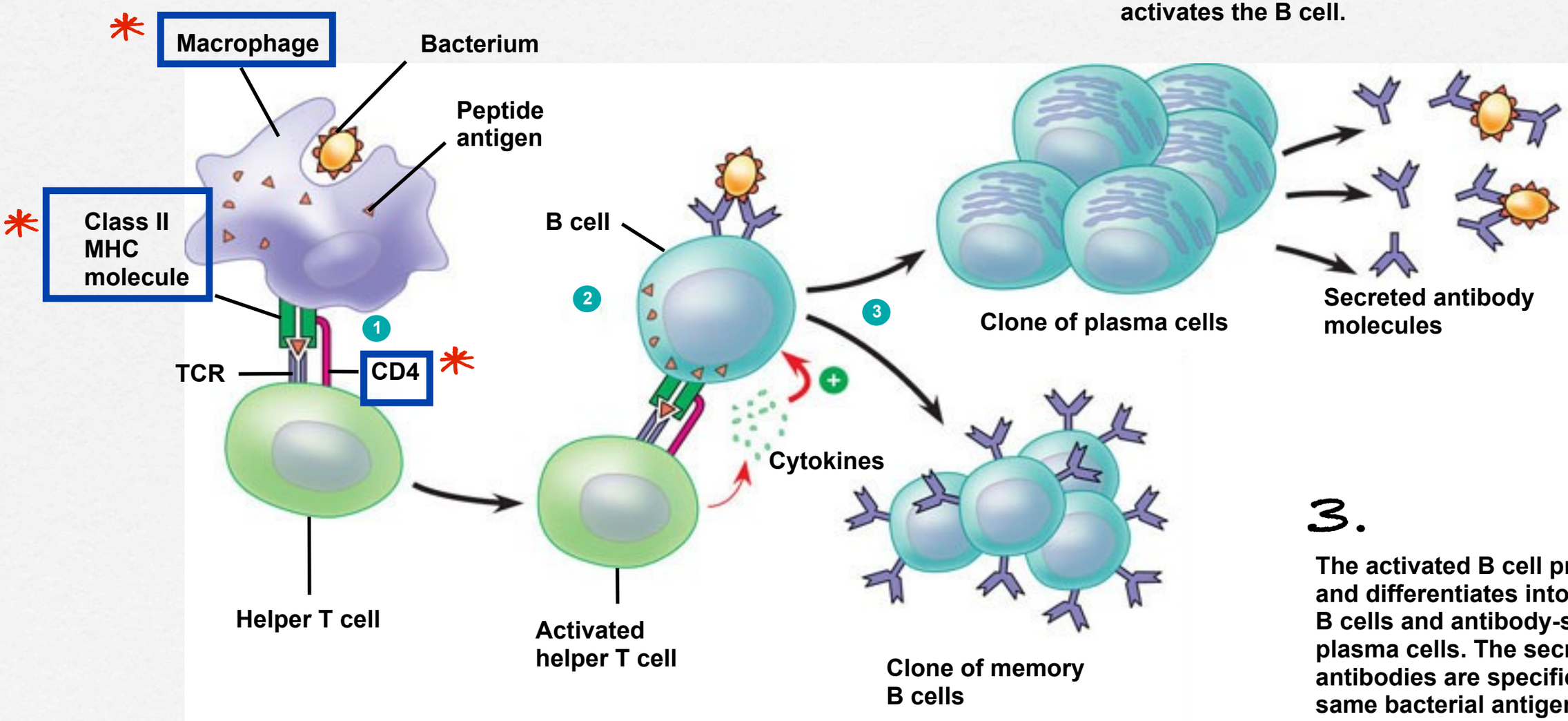


Humoral Immune Response

If macrophage presents antigen it is likely a secondary immune response

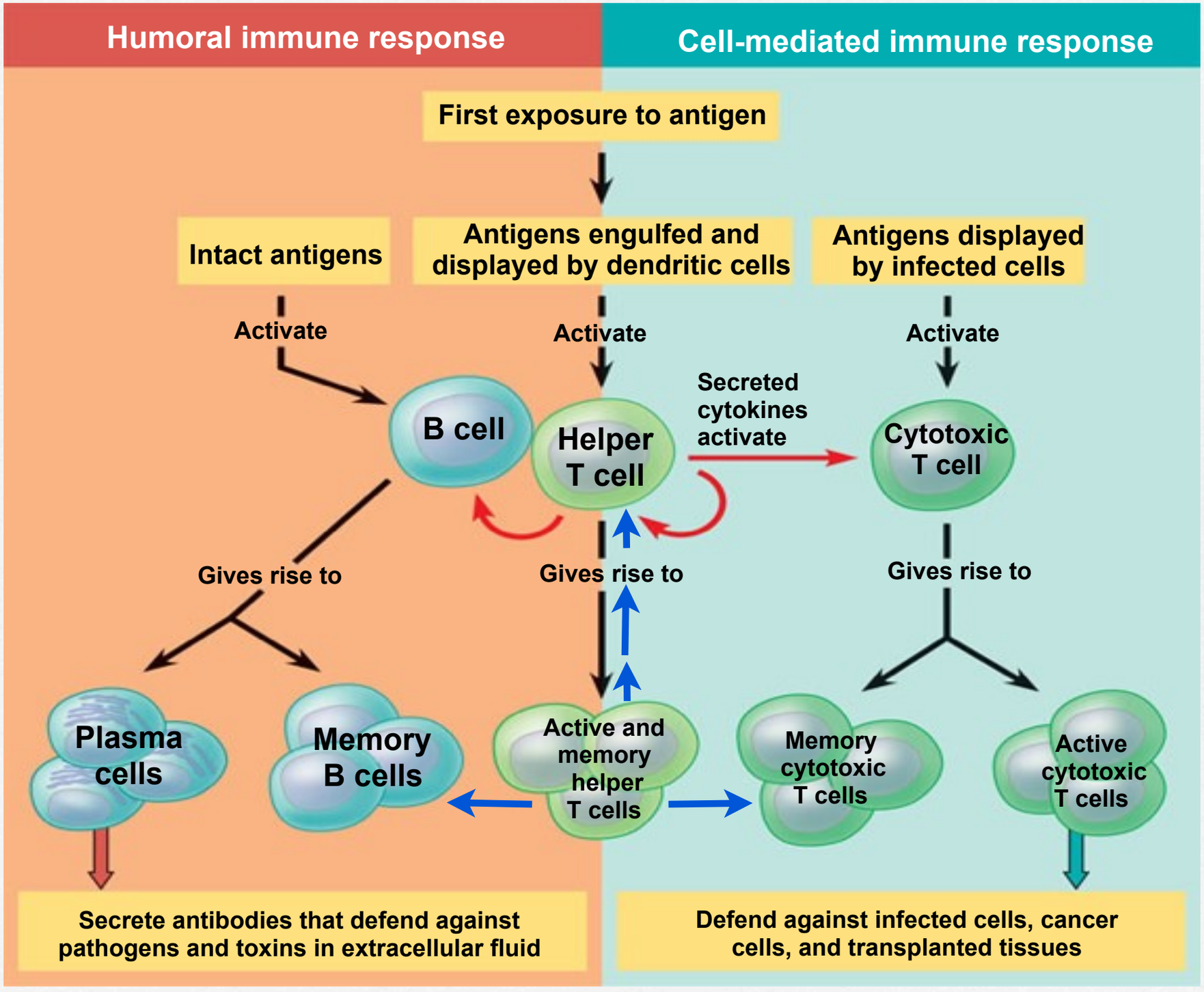
1. After a macrophage engulfs and degrades a bacterium, it displays a peptide antigen complexed with a class II MHC molecule. A helper T cell that recognizes the displayed complex is activated with the aid of cytokines secreted from the macrophage, forming a clone of activated helper T cells (not shown).

2. A B cell that has taken up and degraded the same bacterium displays class II MHC–peptide antigen complexes. An activated helper T cell bearing receptors specific for the displayed antigen binds to the B cell. This interaction, with the aid of cytokines from the T cell, activates the B cell.



3. The activated B cell proliferates and differentiates into memory B cells and antibody-secreting plasma cells. The secreted antibodies are specific for the same bacterial antigen that initiated the response.

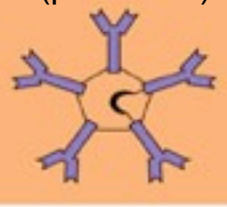
Overview Of Acquired Immunity



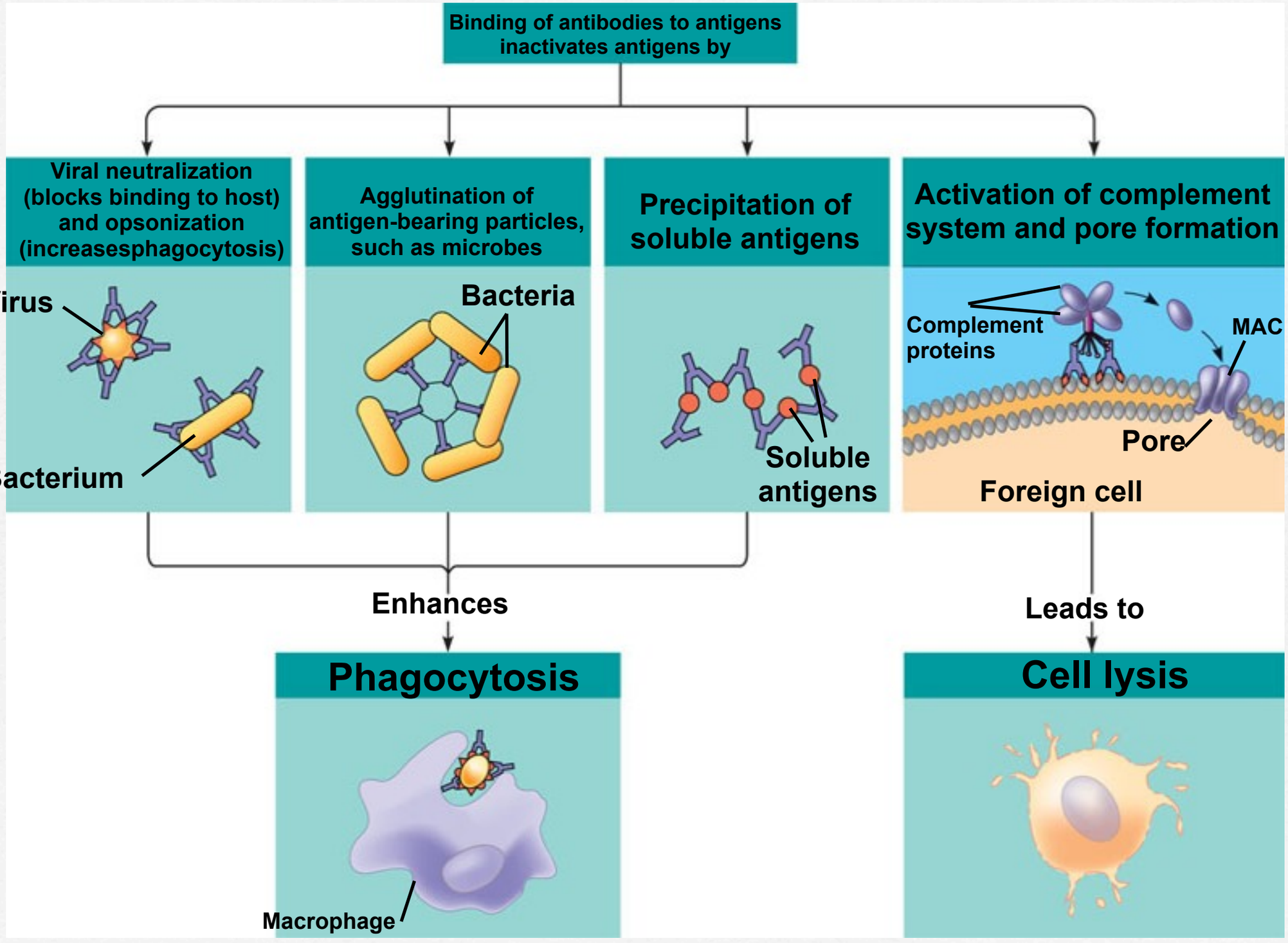
First Exposure

Second Exposure

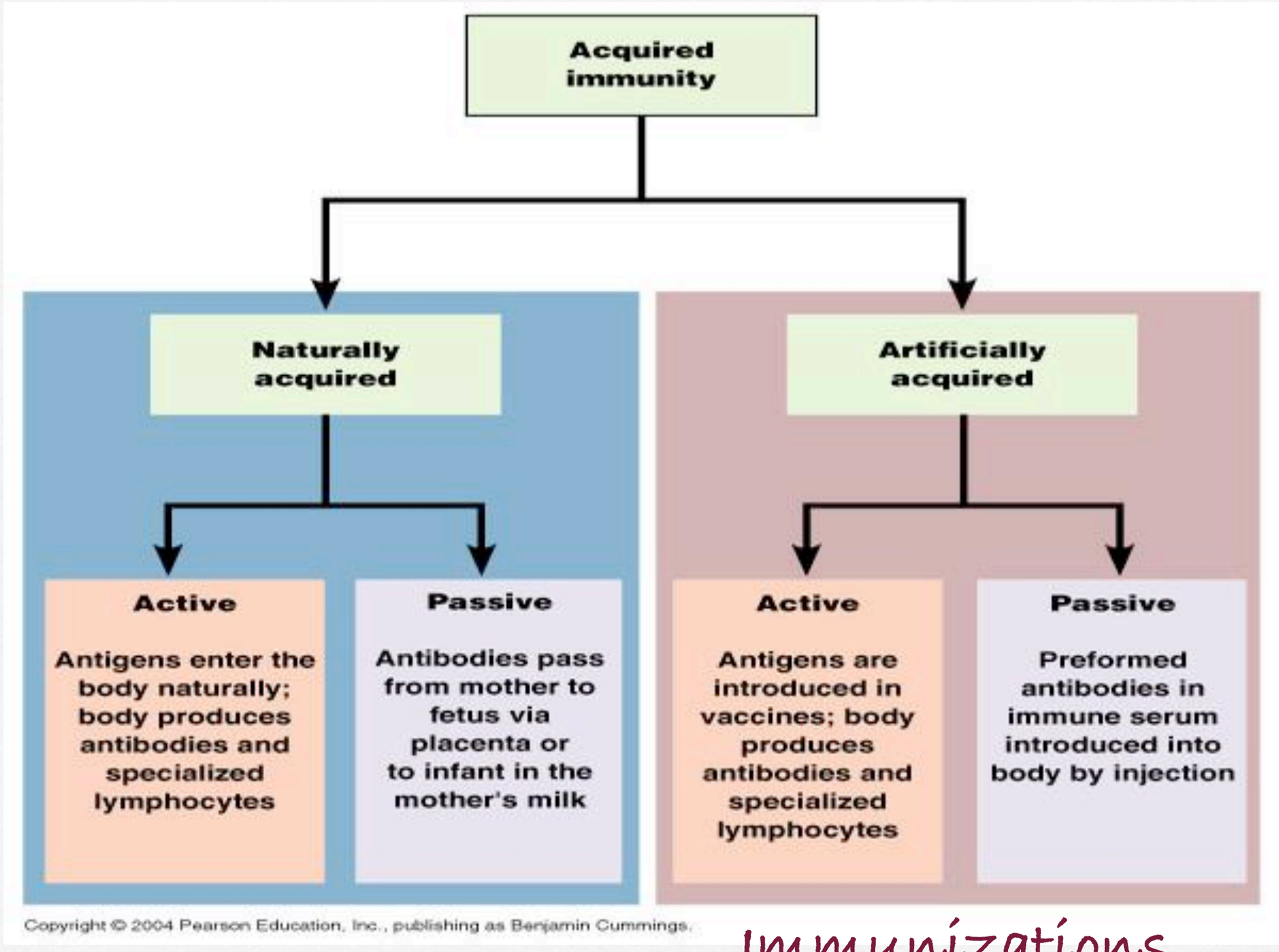
5 Classes of Immunoglobulins

IgM (pentamer) 	► First Ig class produced after initial exposure to antigen; then its concentration in the blood declines ► Promotes neutralization and agglutination of antigens; very effective in complement activation
IgG (monomer) 	► Most abundant Ig class in blood; also present in tissue fluids ► Only Ig class that crosses placenta, thus conferring passive immunity on fetus ► Promotes opsonization, neutralization, and agglutination of antigens; less effective in complement activation than IgM
IgA (dimer) 	► Present in secretions such as tears, saliva, mucus, and breast milk ► Provides localized defense of mucous membranes by agglutination and neutralization of antigens ► Presence in breast milk confers passive immunity on nursing infant
IgE (monomer) 	► Triggers release from mast cells and basophils of histamine and other chemicals that cause allergic reactions
IgD (monomer) 	► Present primarily on surface of naive B cells that have not been exposed to antigens ► Acts as antigen receptor in antigen-stimulated proliferation and differentiation of B cells (clonal selection)

Antibody Mechanisms of Action



Active & Passive Immunity



Immunizations

Active & Passive Immunity

- **Active: Natural or Artificial**
  - slower to acquire immunity but lasts much longer
  - involves patient's T cells or B cells thus memory develops

- **Passive: Natural or Artificial**
  - immediate immunity but lasts only for a few weeks/months
  - does not involve patient's T cells or B cells

Immunizations / Vaccinations

- **Active or Passive Immunity: "Artificially"**
  - 1796 Edward Jenner noticed milkmaids were immune to severe and dangerous smallpox symptoms
  - Edward Jenner injects people with cowpox virus (antigens)
    - (a weak but similar virus to smallpox)
  - cowpox antigen generates active immunity including memory against cowpox and smallpox
  - Today's vaccines might include weakened toxins, killed pathogens, pathogen pieces or weakened pathogens

What can we deduce about the cowpox virus if it can serve as a smallpox vaccine?

The surface of each virus must be very similar

Antibodies as Tools

- **Monoclonal Antibodies**
  - The power of antibody-antigen specificity has been harnessed in research, diagnosis and therapy.
  - Monoclonal antibodies- produced in culture for specific epitopes on an antigen
    - monoclonal antibodies in home pregnancy tests detect HCG a hormone that is released when embryo attaches to uterus
    - using mice to create human antibodies that can be injected into patients

Immune Rejection- Blood Groups

- **Keep in mind blood, tissue and organ rejection is a sign of a healthy immune system!**

Table 43.1 Blood Groups That Can and Cannot Be Safely Combined in Transfusion*

Recipient's Blood Group	Antibodies in Recipient's Blood	Presence (+) or Absence (–) of Tranfusion Reaction: Donated Blood Group (Packed Cells)			
		A	B	AB	O
A	Anti-B	–	+	+	–
B	Anti-A	+	–	+	–
AB	No anti-A or anti-B	–	–	–	–
O	Anti-A and anti-B	+	+	+	–

* Individuals with type AB blood are universal recipients (blue row); those with type O blood are universal donors (green column).

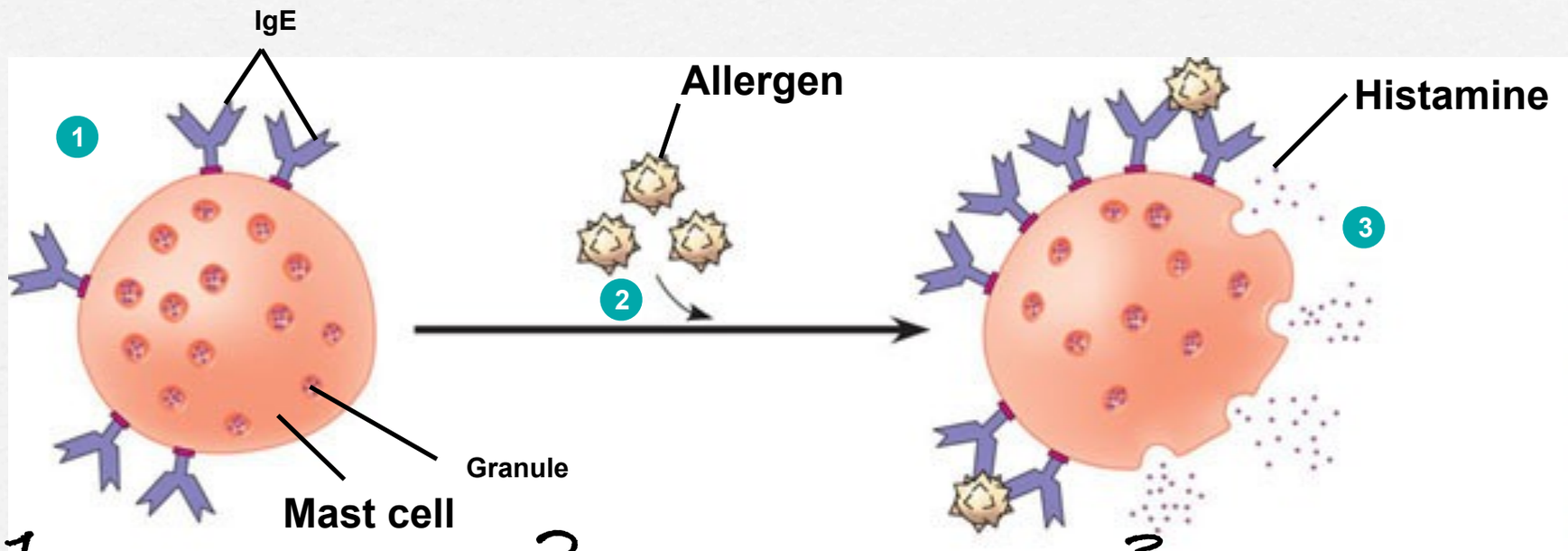
Immune Rejection- Transplants

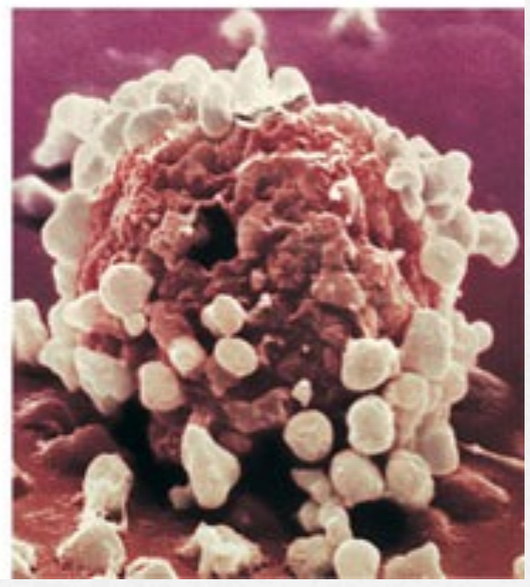
- **The diversity of MHC molecules ("cell ID Tags") guarantees that <u>almost no two people</u> with have the same markers.** ?
  - The trick with tissue/organ transplants is to find donors that have very similar MHC molecules.
  - Often this is not enough and tissue/organ recipients require life long drug regimens that suppress their immune system as well.
  - The rejected tissue can also occur when donor tissue rejects recipients...consider bone marrow transplants.

Identical twins have identical MHC molecules

Immune Disorders- Allergies

- **Allergies are hypersensitive responses to certain antigens called allergens.**





1. IgE antibodies produced in response to initial exposure to an allergen bind to receptors or mast cells.

2. On subsequent exposure to the same allergen, IgE molecules attached to a mast cell recognize and bind the allergen.

3. Degranulation of the cell, triggered by cross-linking of adjacent IgE molecules, releases histamine and other chemicals, leading to allergy symptoms.

- Antihistamines can diminish allergy symptoms and inflammation by blocking histamine receptors on cell surfaces.

Disorders- Autoimmune Diseases

- **In some the immune system loses the ability to distinguish "self" and "non-self".**
  - *Lupus*
  - *Rheumatoid Arthritis*
  - *Type I Diabetes*
  - *Multiple Sclerosis*
  - Gender, genetics and environment all influence susceptibility to autoimmune disorders.

HOMEWORK: BRIEFLY RESEARCH ONE DISORDER AND BE ABLE TO DISCUSS AND EXPLAIN THAT DISORDER IN CLASS

Plants

Defense

Main Idea

- *Life is faced with a number of threats.*
  - *These threats include biotic factors like predators, pathogens, and parasites.*
  - *Even extreme abiotic factors can threaten the life.*
- *Living organisms defend themselves by using four general strategies protective barriers, fleeing, hiding, or fighting back.*
  - *Plants however can not flee or hide.*

Preface to Plant Defenses

- ***Plants face threats at both the organismal level and at the cellular.***
  - ***Herbivores attack the organism itself.***
  - ***Pathogens and parasites attack the cells of the organism.***
- **This presentation will address defense mechanisms against herbivory and defense against pathogens separately.**

Plant Defenses against Herbivores

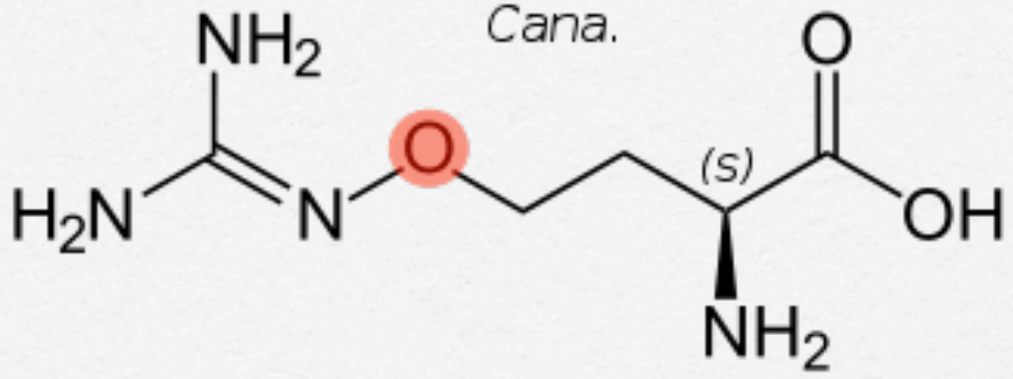
- **PROTECTIVE & PHYSICAL BARRIERS**

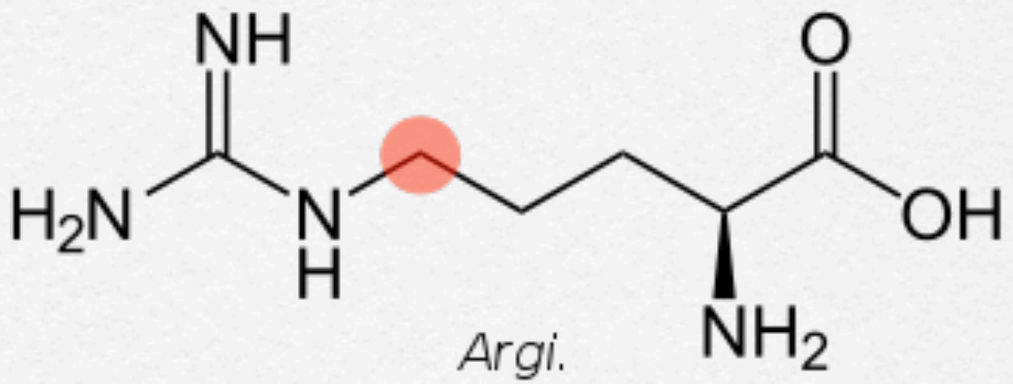
- **Plant barriers include bark, spines, thorns, trichomes (hairs).**

Plant Defenses against Herbivores

- **CHEMICAL DEFENSES**
- **Plants can produce distasteful or toxic chemicals.**
  - Canavanine is a chemical that resembles the amino acid arginine.
  - It is different enough that organisms that build proteins with it have misshapen proteins.
  - These misshaped proteins do function properly and the organism dies.

Canavanine vs Arginine



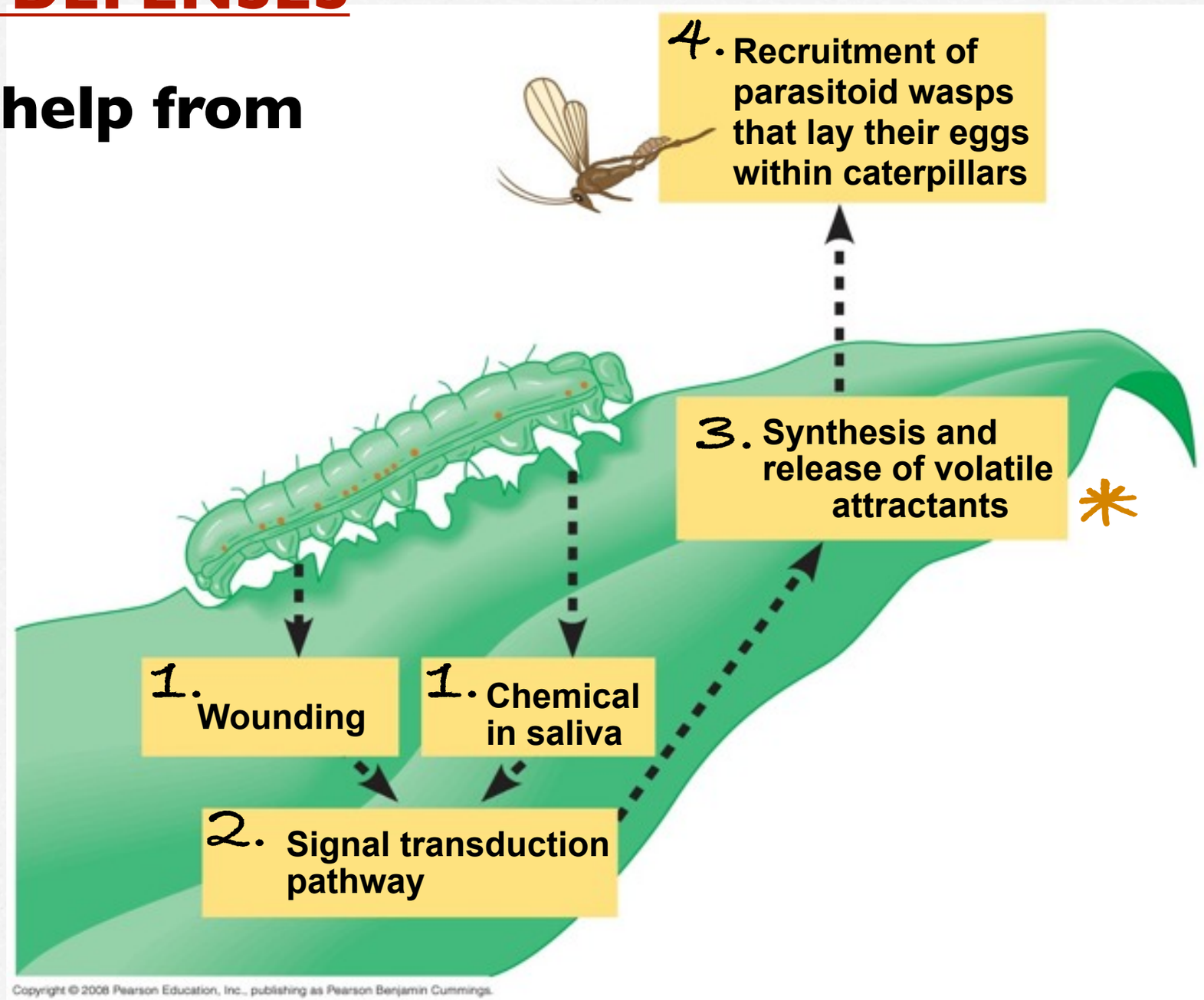


Structure Dictates Function

Plant Defenses against Herbivores

- **RECRUITMENT DEFENSES**
- **Plants can elicit help from other species.**

* These volatile attractants can also warn nearby plants, so that they might make biochemical changes that make them less susceptible themselves



Plant Defenses against Pathogens

- **1st Line of Defense- PHYSICAL BARRIERS**
- Remember the first and most fundamental barrier is the plasma membrane and cell wall itself.
- **Plant barriers include the periderm and epidermis (basically bark).**
  - Unfortunately these barriers are not impenetrable.
- **2nd Line of Defense- CHEMICAL ATTACK**
- Chemicals destroy pathogens and prevents its spread from site of infection.
- Similar to animals, plants can recognize certain pathogens

Host-Pathogen Coevolution

- **Virulent** pathogens kill the host.
- **Avirulent** pathogens do not kill the host.

Which of the two is more common? Why?

Avirulent is more common; if not then the host and pathogen would perish together

Host-Pathogen Coevolution

- **Oddly enough this host-pathogen coevolution illustrates yet another example of "Trade-Offs" common in nature.**
  - Complete resistance is energetically very expensive to the plant
    - this would make less able to compete for other resources
  - No resistance is energetically very inexpensive to the plant but would kill the plant
  - Thus we find a compromise between pathogen and host.
    - The best pathogens gain access to plant to perpetuate itself but does not severely damage the plant.

Do you think the same applies to bacterial and viral infections of animals?

YEP!

Gene for Gene Recognition

- **Plants have hundreds of resistance genes (R) that code for pathogen derived molecules called effectors**
  - It is simple...if the plant does not have the R genes to recognize the pathogen then the pathogen redirects its metabolism to its advantage BUT if the plant has the R genes to recognize the pathogen then an arsenal of defenses are released.
  - See next slides

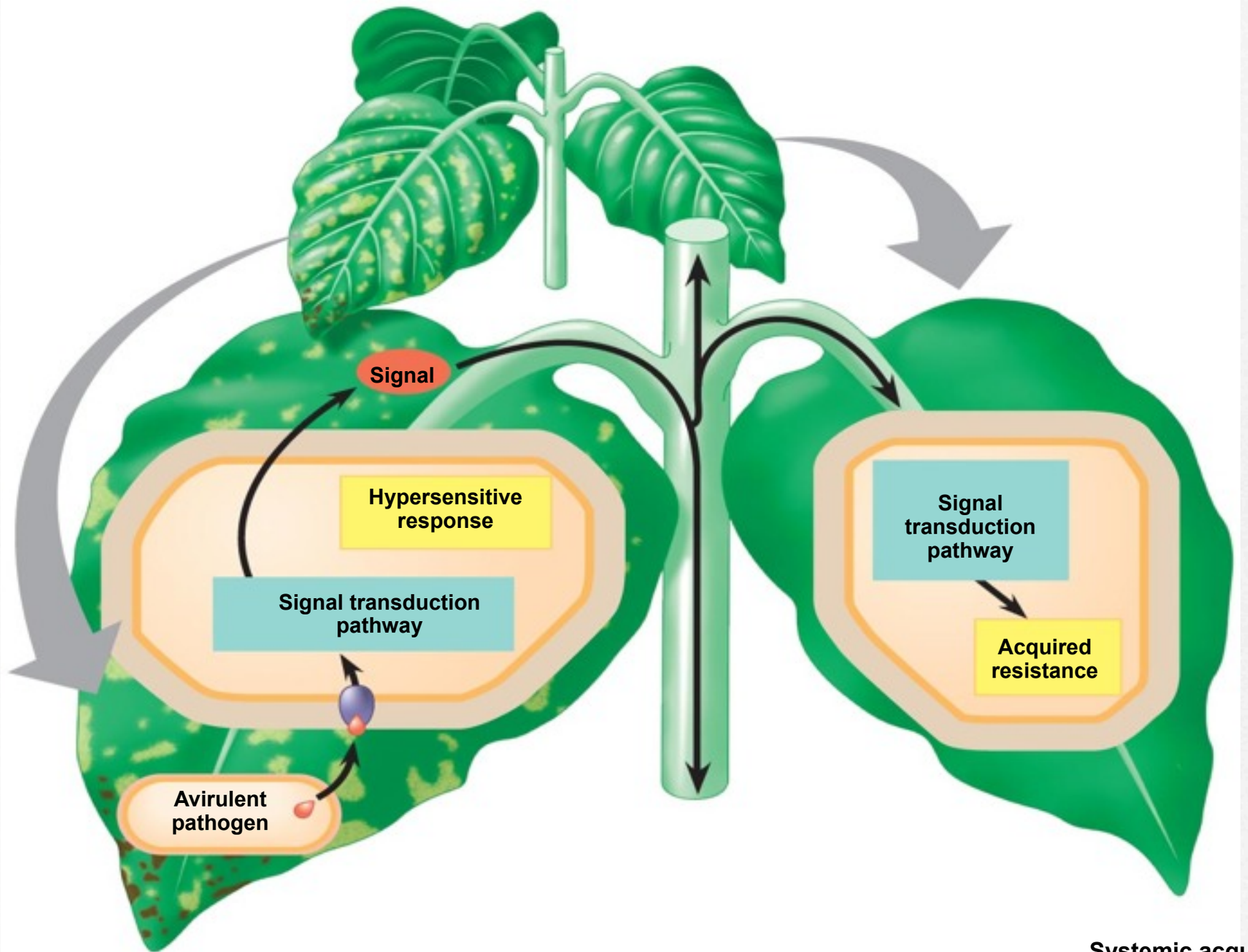
The Hypersensitive Response

- **Hypersensitive Response** is a defense response that causes tissue death near the infection site, thus restricting spread of pathogen.
  - Chemical attack occurs
    - ***phytoalexins*** *that have fungicidal and bactericidal properties along with hydrolytic enzymes are released*
  - Area is sealed off
    - lignin and cross-linking of molecules reinforces the cell wall to hinder spread of infection
  - Infected cells destroy themselves
    - infected cells under go apoptosis to save other cells

Systemic Acquired Resistance

- **Systemic Acquired Resistance** arises from a plant wide expression on defense genes.
  - It is non-specific and provides protection that lasts for days
  - It is a chemical "alarm call" for the entire plant
  - *Methylsalicyclic acid* is produced around infection site, carried by phloem to rest of plant, *methylsalicyclic acid* is converted to ***salicyclic acid*** which promotes the production of proteins specific against the attacking pathogen.

Systemic Acquired Resistance



R-Avr recognition and hypersensitive response

Systemic acquired resistance

Remember

- ***Plant life is faced with a number of threats.***
  - ***Even extreme abiotic factors can threaten the life of plants.***
  - Extreme temperatures, salty soils, floods, droughts and mechanical pressures are examples of abiotic threats.
  - Plants DO have mechanisms for dealing with each and everyone of these.
  - The details for each have been or will covered in other “common challenges” units

Fungi

Defense

Main Idea

- ***Fungi are faced with a number of threats.***
  - ***These threats include biotic factors like other bacteria, viruses, and cells of animal immune systems.***
  - ***Even extreme abiotic factors can threaten the life.***
- ***Fungi defend themselves by using general strategies such as protective barriers and fighting back.***

General Fungal Defenses

- **PROTECTIVE BARRIERS**
- The first and most fundamental barrier is the **plasma membrane** itself.
- An additional protective barrier for fungi is their **cell walls**.
  - Recall that the cell wall keeps the fungal cell from bursting when introduced into a hypoosmotic environment.
  - The cell walls may also protect them from a variety of biotic threats

General Fungal Defenses

- **CHEMICAL DEFENSES**
- Some fungi produce *antibiotics*, chemicals that kill certain bacteria.
- In 1928, Alexander Flemming showed that the fungus *Penicillium rubens* released a substance that had antibiotic properties.
- This substance would be known as penicillin and the era of antibiotic discovery began.
- The discovery of penicillin was as Flemming admits... an accident.
- Penicillin was successful in a handful cases during the 1930's
- The mass production began during WWII
- It is the most widely administered antibiotic to date

General Fungal Defenses

- **CHEMICAL DEFENSES**
- Antibiotics have different mechanisms of action
  - They destroy bacterial cell walls.
    - Some target the plasma membrane
  - They interfere with bacterial metabolism (enzymes).
    - Some block protein synthesis
    - Yet others interfere with reproduction

Pathogenic Fungal Defenses

There are a variety of additional defenses found in pathogens some of these may also be found in in pathogenic fungi.

This will be discussed later in the bacteria section where we discuss pathogens in general.

Protists

Defense

Main Idea

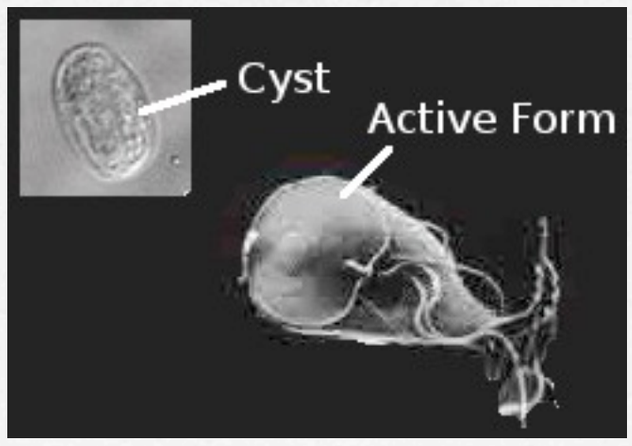
- ***Protista are faced with a number of threats.***
  - ***These threats include biotic factors like bacteria, viruses, and cells of animal immune systems.***
  - ***Even extreme abiotic factors can threaten the life.***
- ***Protista defend themselves by using general strategies such as protective barriers, fleeing, hiding, or fighting back.***

General Protistan Defenses

- **PROTECTIVE BARRIERS**
- The first and most fundamental barrier is the **plasma membrane** itself.
- Only some protists however have **cell walls**.
  - Animal like protists- the protozoa do not have cell walls.
  - Algae do have however cell walls.
- Some protists also possess have **pellicles,** a thin layer that supports the plasma membrane.
- Some have armor plates made of cellulose, this protective covering is known as the **theca**.

Protistan Defense Against Harsh Abiotic Conditions

- **Cysts**
- When environmental conditions become hostile some protists can form tough, protective coat
- Cysts allow certain protists to lie dormant until conditions improve.
- Cysts differ from bacterial endospores (learn about later) in their composition and degree of resistance
  - EX. *Entamoeba hystolytica* (dysentary)
  - EX. *Giardia lamblia* (Montezuma's Revenge)

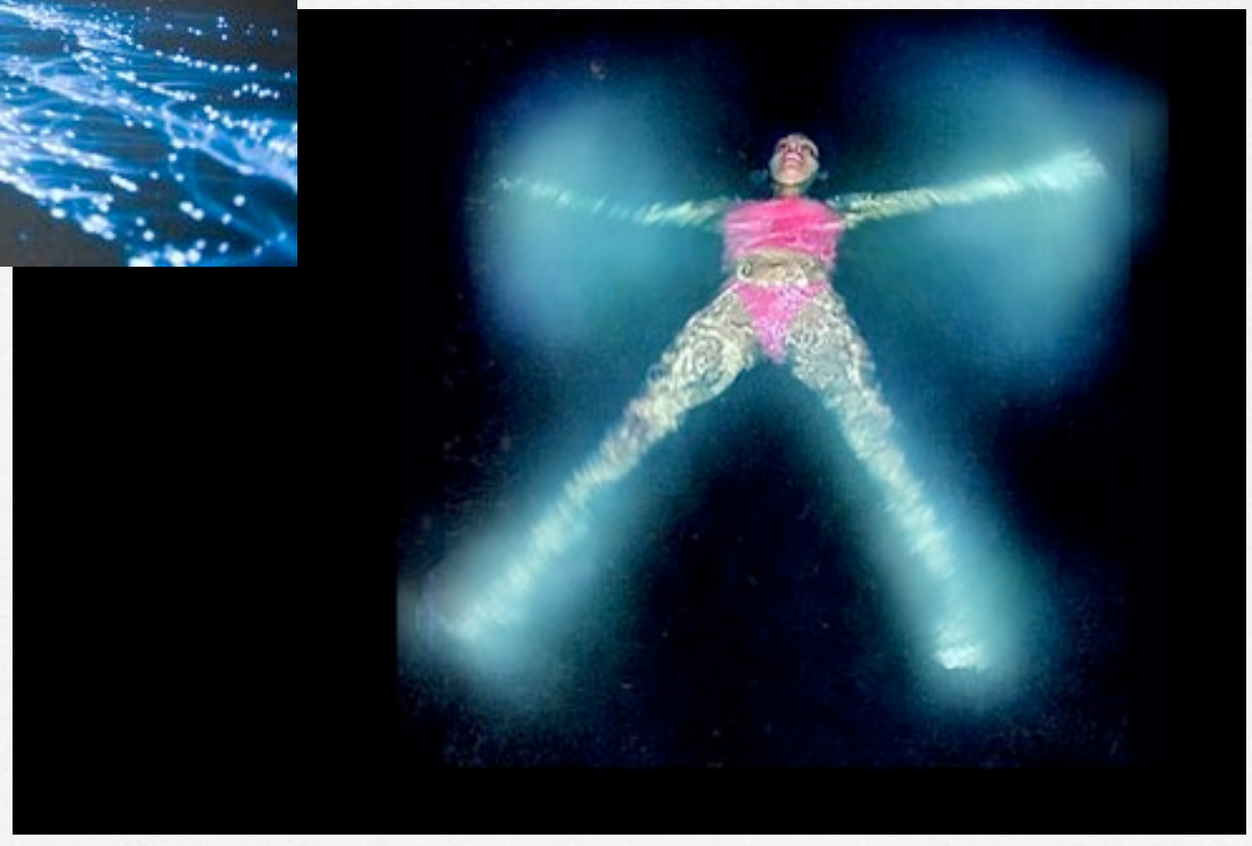


Protistan Defense Against Predators

- **Bioluminescence**
- Some protists emit a blue-green light
  - They emit the light to startle predators
  - They can flash the light on and off like a burglar alarm to ward off predators
  - The light can draw attention to itself so that its predator is now more vulnerable to predators from a higher trophic level.
    - these bioluminescent protists are the both rare and fragile

Bioluminescence

Agitation activates the defensive response



Bioluminescence

Pathogenic Protists Defenses

There are a variety of additional defenses found in pathogens some of these may also be found in in pathogenic protists.

This will be discussed later in the bacteria section where we discuss pathogens in general.

Bacteria

Defense

Main Idea

- ***Bacteria are faced with a number of threats.***
  - ***These threats include biotic factors like bacteria, viruses, and cells of animal immune systems.***
  - ***Even extreme abiotic factors can threaten the life.***
- ***Bacteria defend themselves by using general strategies such as protective barriers, fleeing, hiding, or fighting back.***

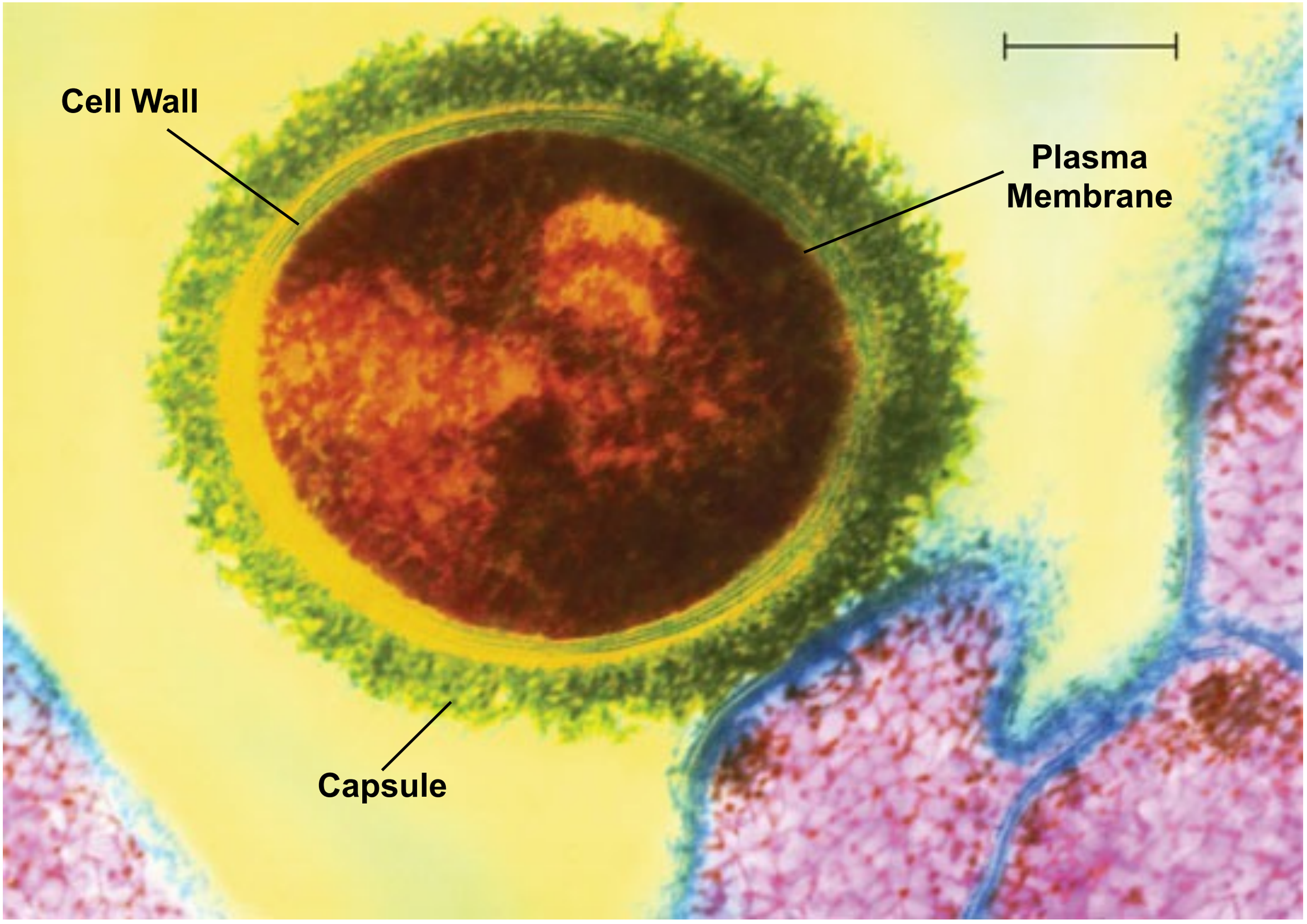
Preface to Bacterial Defenses

- ***Bacteria face a number threats.***
  - ***Unfavorable environmental conditions***
  - ***Viruses can attack bacteria.***
  - ***Immune Systems of animals attack bacteria.***
    - The propagation of a pathogen depends on its ability to replicate in a host and move to another host
    - The very best pathogens do not elicit an immune response or evade the immune response once it has occured
    - Over millions of years pathogens have co-evolved with their hosts, they have developed defensive strategies against immune system attacks.

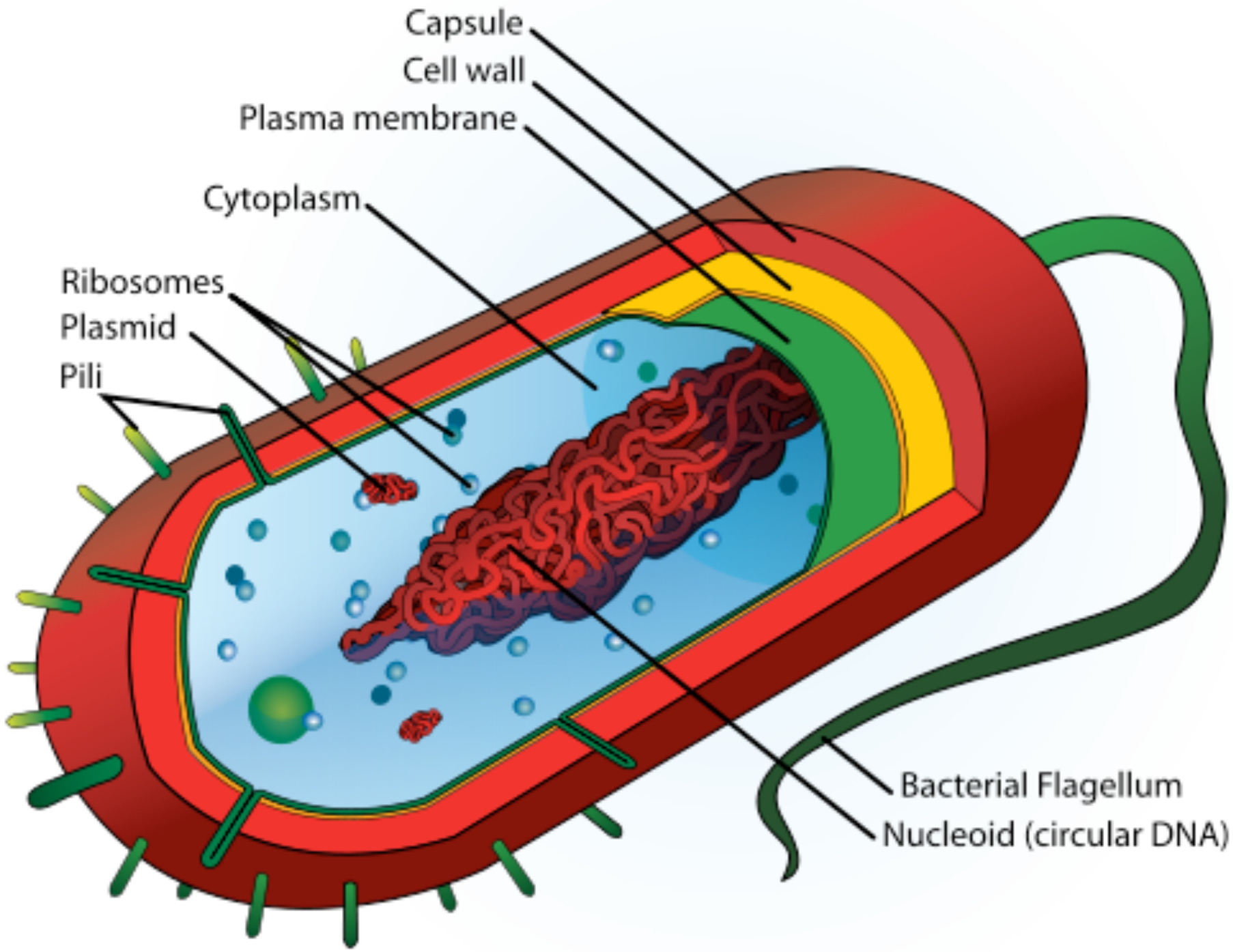
General Bacterial Defenses

- **PROTECTIVE BARRIERS**
- The first and most fundamental barrier is the **plasma membrane** itself.
- The key protective barrier for bacteria is however their **cell walls**.
  - Recall that the cell wall keeps the bacterial cell from bursting when introduced into a hypoosmotic environment.
  - The cell walls protect them from a variety of biotic threats
- Many bacteria have a sticky or slime layer around the cell wall called a **capsule** that provides an additional layer of protection.

Protective Barriers in Bacteria



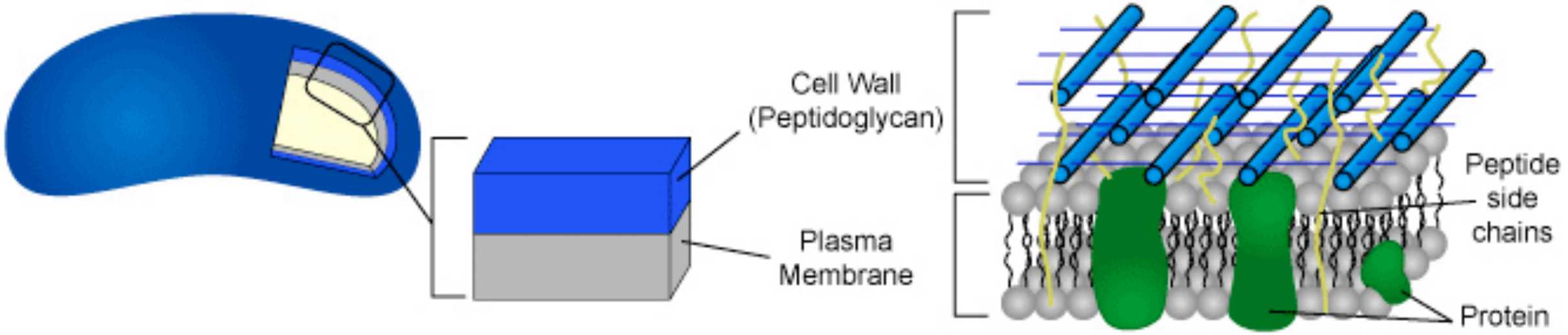
Bacterial Capsules



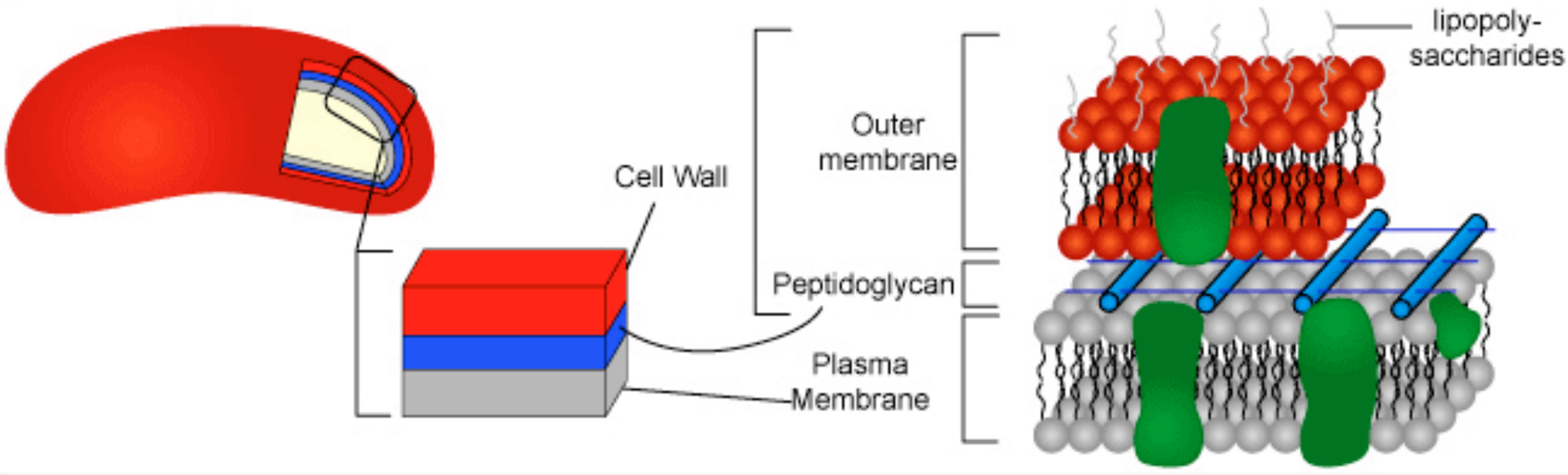
Bacterial Cell Walls

Bacterial cell walls are different from eukaryotic cell walls like those found in fungi and plants. Plants and fungal cell walls are composed of cellulose or chitin. Bacterial cell walls are composed of peptidoglycan, a sugars crossed linked with polypeptides.

Gram^{+} Bacteria

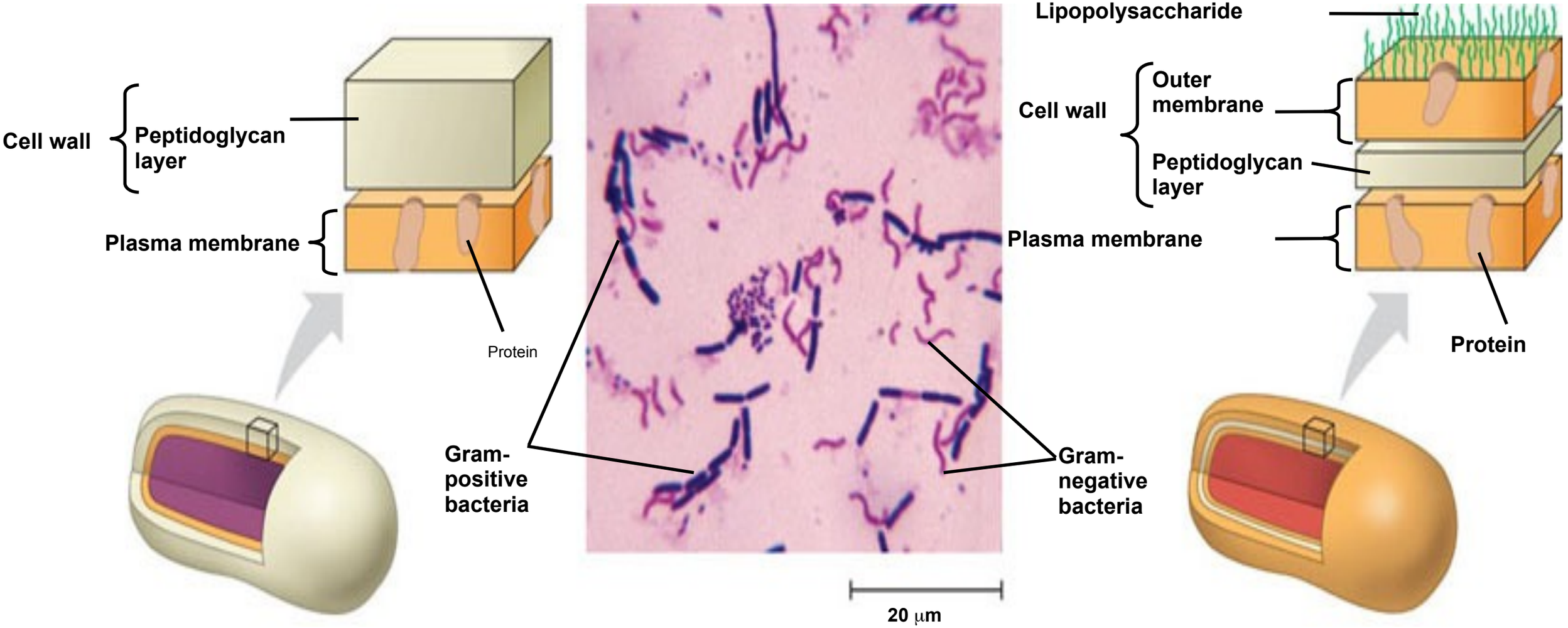


Gram^{-} Bacteria



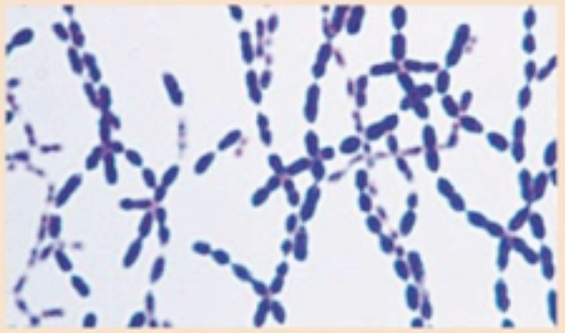
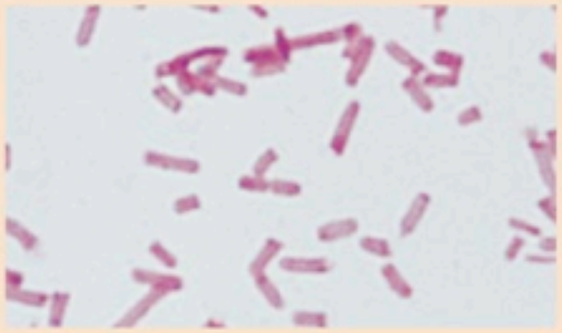
Gram Staining

Gram staining separates bacteria into two groups based upon the structure of their cell walls.



(a) **Gram-positive. Gram-positive bacteria have a cell wall with a large amount of peptidoglycan that traps the violet dye in the cytoplasm. The alcohol rinse does not remove the violet dye, which masks the added red dye.**

(b) **Gram-negative. Gram-negative bacteria have less peptidoglycan, and it is located in a layer between the plasma membrane and an outer membrane. The violet dye is easily rinsed from the cytoplasm, and the cell appears pink or red after the red dye is added.**

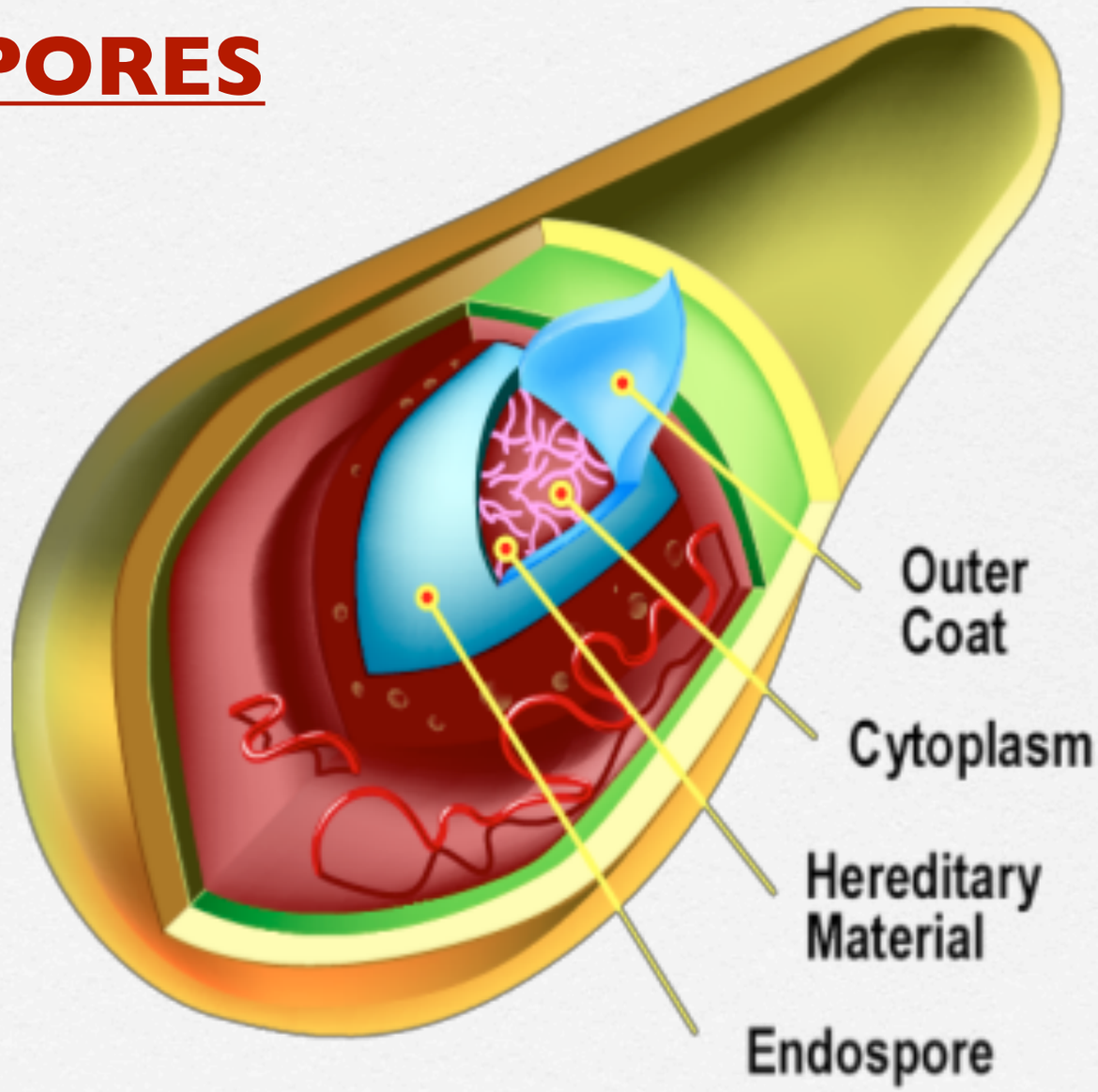
Characteristic	Gram-Positive	Gram-Negative
	 LM 4 μm	 LM 4 μm
Gram Reaction	Retain crystal violet dye and stain blue or purple	Can be decolorized to accept counterstain (safranin) and stain pink or red
Peptidoglycan Layer	Thick (multilayered)	Thin (single-layered)
Teichoic Acids	Present in many	Absent
Periplasmic Space	Absent	Present
Outer Membrane	Absent	Present
Lipopolysaccharide (LPS) Content	Virtually none	High
Lipid and Lipoprotein Content	Low (acid-fast bacteria have lipids linked to peptidoglycan)	High (because of presence of outer membrane)
Flagellar Structure	2 rings in basal body	4 rings in basal body
Toxins Produced	Exotoxins	Endotoxins and exotoxins
Resistance to Physical Disruption	High	Low
Cell Wall Disruption by Lysozyme	High	Low (requires pretreatment to destabilize outer membrane)
Susceptibility to Penicillin and Sulfonamide	High	Low
Susceptibility to Streptomycin, Chloramphenicol, and Tetracycline	Low	High
Inhibition by Basic Dyes	High	Low
Susceptibility to Anionic Detergents	High	Low
Resistance to Sodium Azide	High	Low
Resistance to Drying	High	Low

Bacterial Defense Against Harsh Abiotic Conditions

- **ENDOSPORES**
- When environmental conditions become hostile some bacteria can form tough, protective coat around its DNA called an *endospore*.
- Endospores allow bacteria lie dormant for millions of years or until conditions improve.
- Endospores survive without nutrition and resist extreme heat, freezing, UV radiation, desiccation and chemical disinfectants
  - EX. *Bacillus anthracis* (anthrax)
  - EX. *Clostridium tetani* (tetanus)

Bacterial Defense Against Harsh Abiotic Conditions

- **ENDOSPORES**



Bacterial Defense of Viruses

- **Viral Defenses**

- Some viruses can and do attack bacteria, they all called *bacteriophages*.

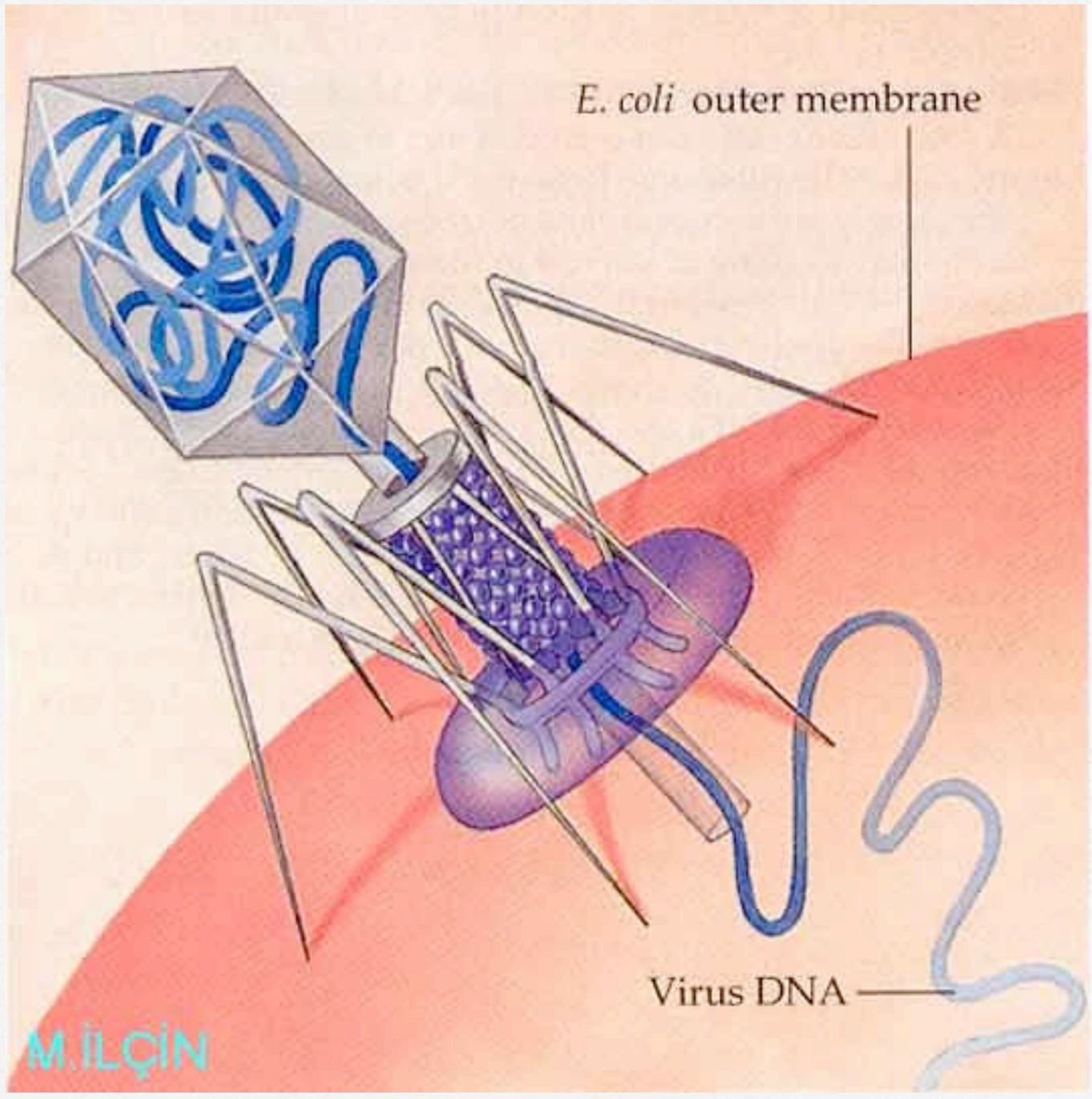
  - Bacteriophages dock to the surface of the bacteria

  - inject its viral DNA, the viral DNA hides among the bacteria's own DNA

  - later the viral DNA takes control of the bacterial cell, instructing to replicate and assemble viral protein components

  - finally as the new viruses emerge from the bacterial host the host dies.

Bacteriophage Attacking

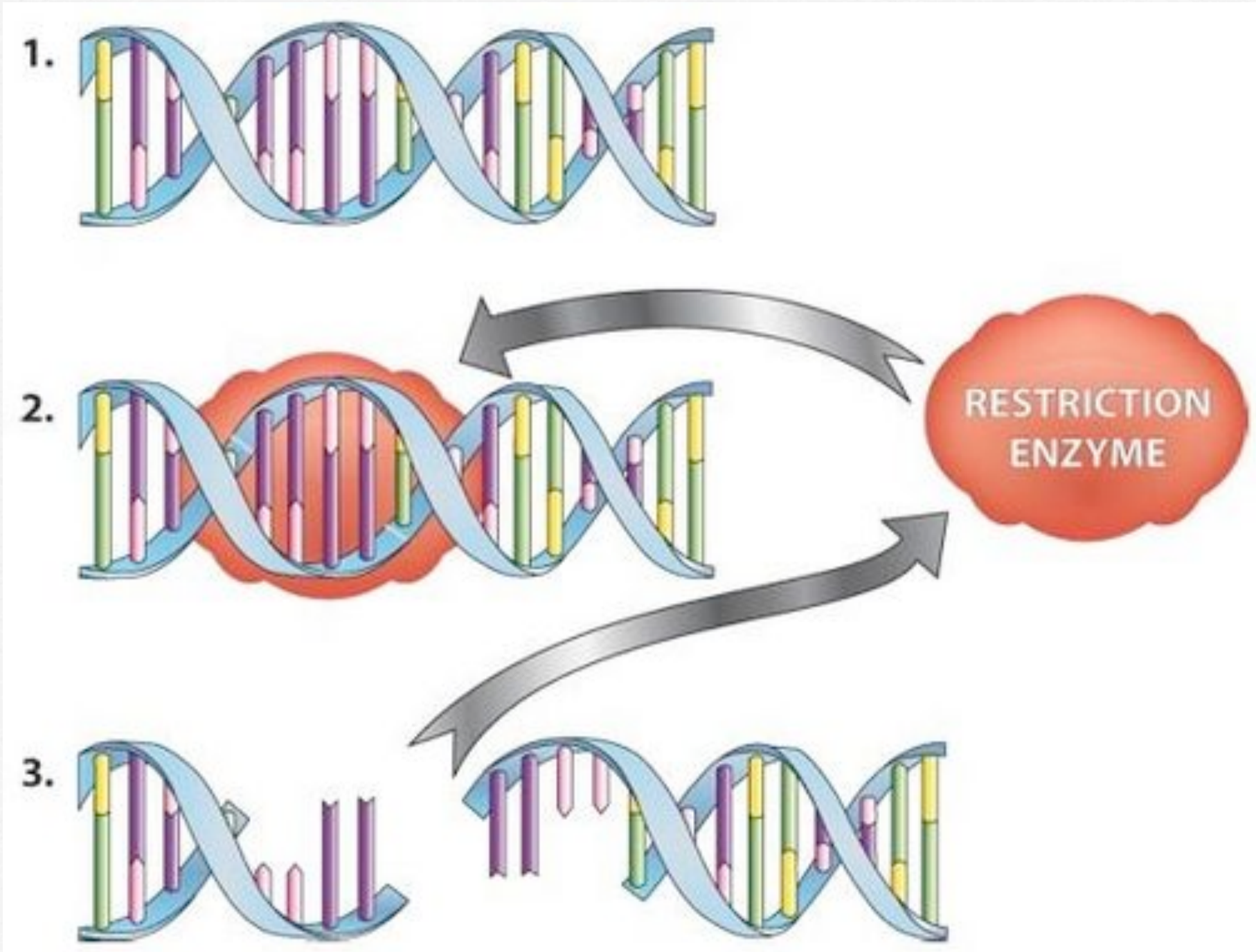


Bacterial Defense of Viruses

- Bacteria Fight Back Against Viral Attacks!
  - **Bacteria posses "*restriction enzymes*" that cut DNA into pieces**
  - if the restriction enzymes find viral DNA in time then the Viral DNA is cut into pieces and the infection is averted
  - bacteria must also protect their own DNA from the restriction enzymes otherwise their DNA would be destroyed as well.

These restriction enzymes are of great value to the field of biotechnology. They are used in gene cloning and other related biotechnologies, also to be discussed later.

Restriction Enzyme Cutting DNA



*Pathogenic Defenses For Immune System Attacks

- **HIDING or FIGHTING BACK?**

- Just as immune systems evolved to better attack pathogens, pathogen evolved to better thwart the attack.

- Antigenic Variation

- Latency

- Attack on The Immune System

*NOTE- It is possible that all types of pathogens: (bacterial, protistan, fungal and viral) as a group employ one or more of these defenses. Due to nature of this course we will only look at one example representation.

*Defenses Against Immune Systems

- **<u>Antigenic Variation</u>, the alteration of surface antigens allows pathogens to escape detection**
- There are 3 Ways in which antigenic variation can occur.
  - Posses a variety of antigenic types
  - Change (via mutation) antigen type over time
  - Change (via gene shuffling & gene expression) antigen type over time

*NOTE- It is possible that all types of pathogens: (bacterial, protistan, fungal and viral) as a group employ one or more of these defenses. Due to nature of this course we will only look at one example representation.

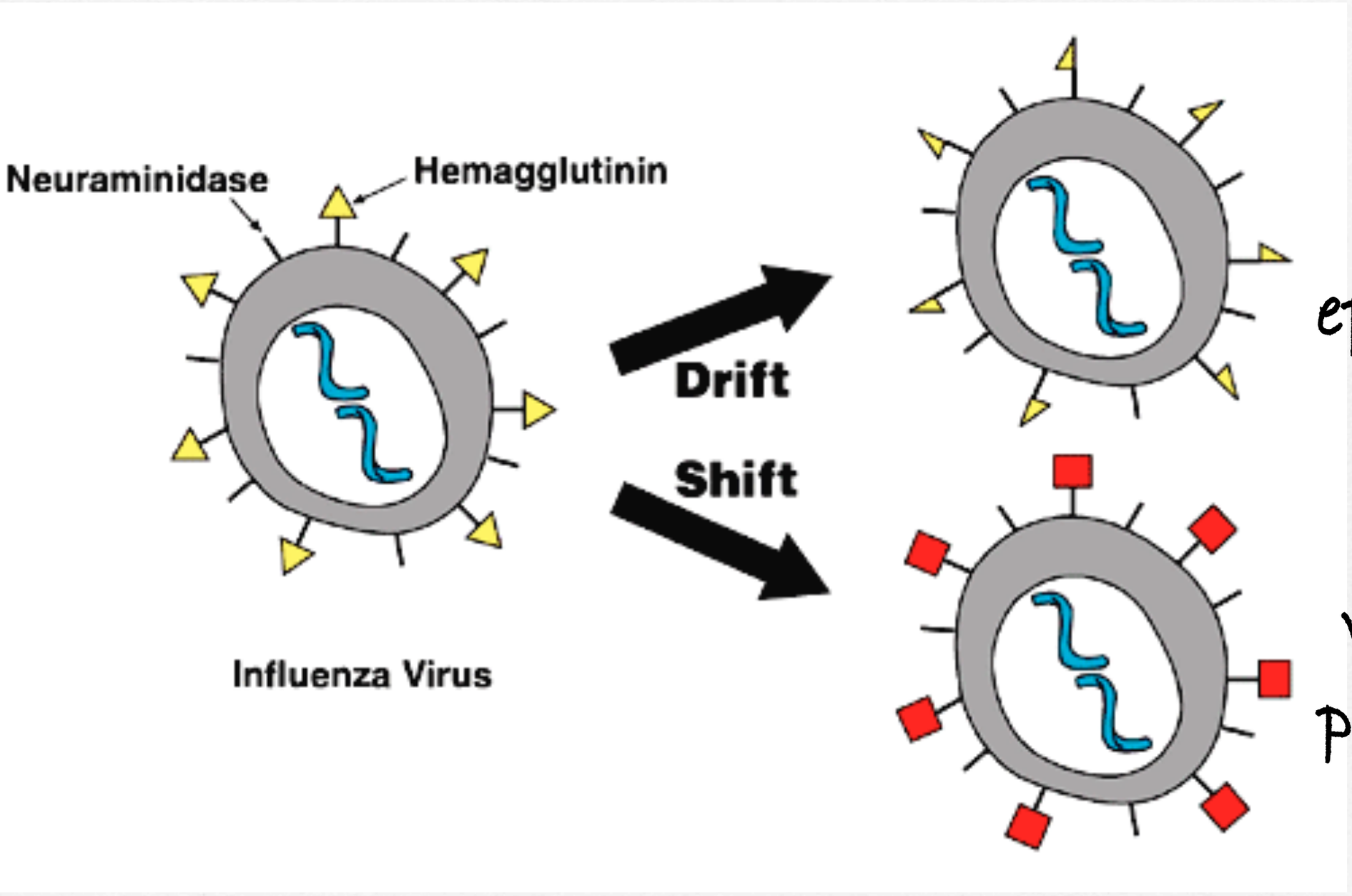
Antigenic Variation

- **Posses a variety of antigenic types**
- Bacterial Example: *Streptococcus pneumoniae*
  - 84 different types exist
  - each type differs in its capsule's antigens
  - this means that the same bacteria has 84 different identities
  - immune systems attack and build memory for one variant at a time, this means that the same bacteria with type antigen could re-infect
  - in other words to the immune system *Streptococcus pneumoniae* be 84 different pathogens

Antigenic Variation

- **Change antigens over time (mutation)**
- Viral Example: *influenza virus*
  - every 2-3 years point mutations in the genes specific for antigen epitopes result in new and novel surface antigens *(antigenic drift)*
    - thus humans can get the same flu virus over and over again even though they have immunological memory because each flu infection is a variant of the same past infection
    - the changes antigenic changes are small and some antibodies in the host react thus epidemics are mild
  - Viral pandemics occur when viral RNA resorts and produces very different and novel antigens which hosts recognize very poorly *(antigenic shift)*

Antigenic Shift vs. Antigenic Drift



bad-
epidemics

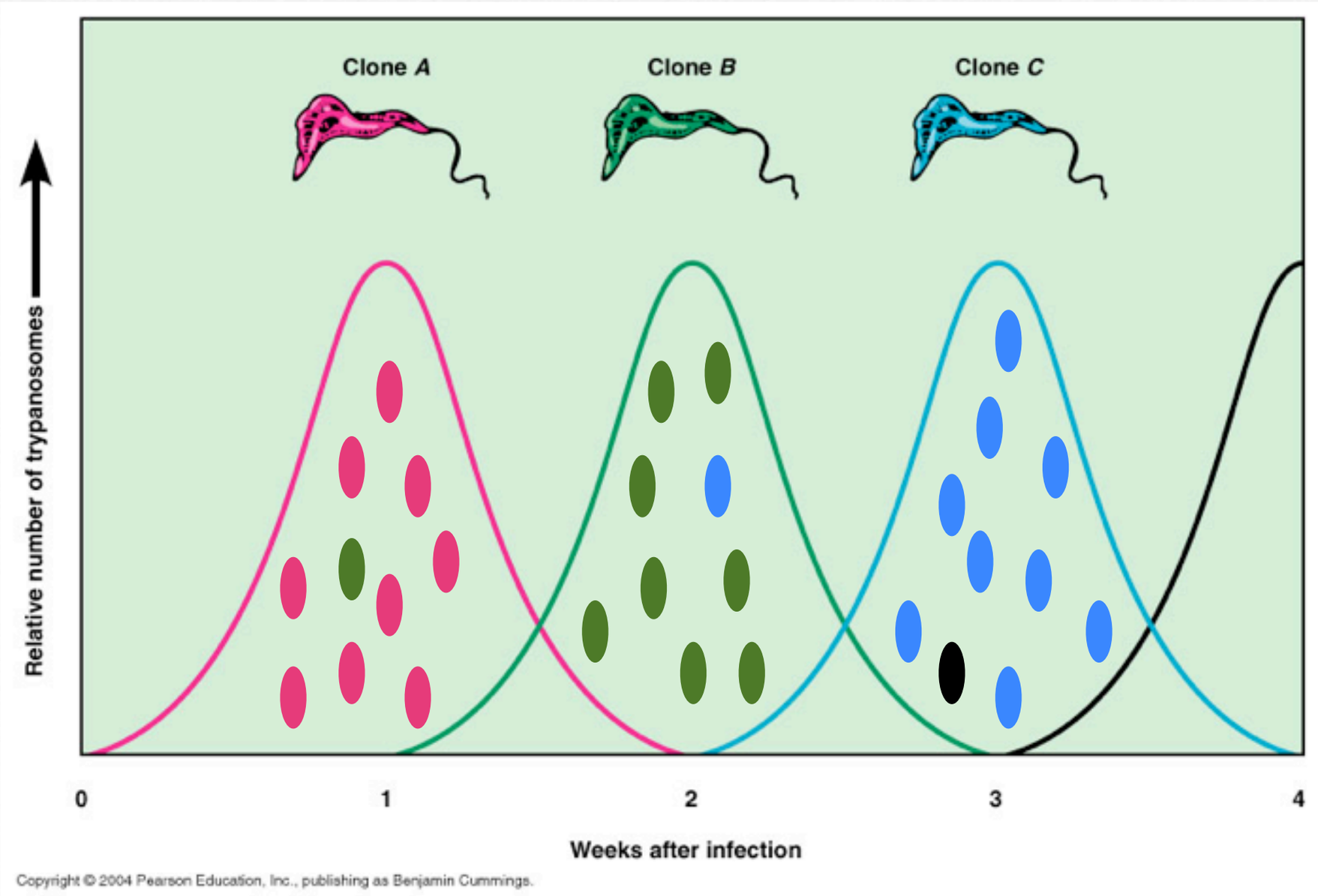
very bad-
pandemics

Antigenic Variation

- **Change antigens over time (gene shuffling/expression)**
- Protistan Example: *Trypanosomes & Plasmodium*
  - these insect borne protists causes "sleeping sickness" and "malaria" in humans
    - Trypanosomes have nearly a 1000 genes that it can use to build its antigens, by shuffling these genes and expressing different genes this organism can create an endless variety of antigen variants.

NOTE- *Salmonella typhimurium*, the bacteria that causes food poisoning and *Neisseria gonnorrhoeae*, the bacteria that causes the STD gonnorrhea also employ this method defense.

Antigenic Variation- Sleeping Sickness



- A few variants escape detection and the infection builds again, this cycle overwhelms the immune system and death is imminent.

Latency

- Viruses require the host to replicate their proteins
  - of course the production of course as these viral proteins are eventually detected by the immune system and the immune response begins
- **Some viruses enter a state where they are transcriptionally "quiet" ...**
  - **thus if no viral proteins are made there are no proteins for the immune system to detect**
- Latency persists until conditions for viral transmission is favorable OR conditions are unfavorable for host's survival.

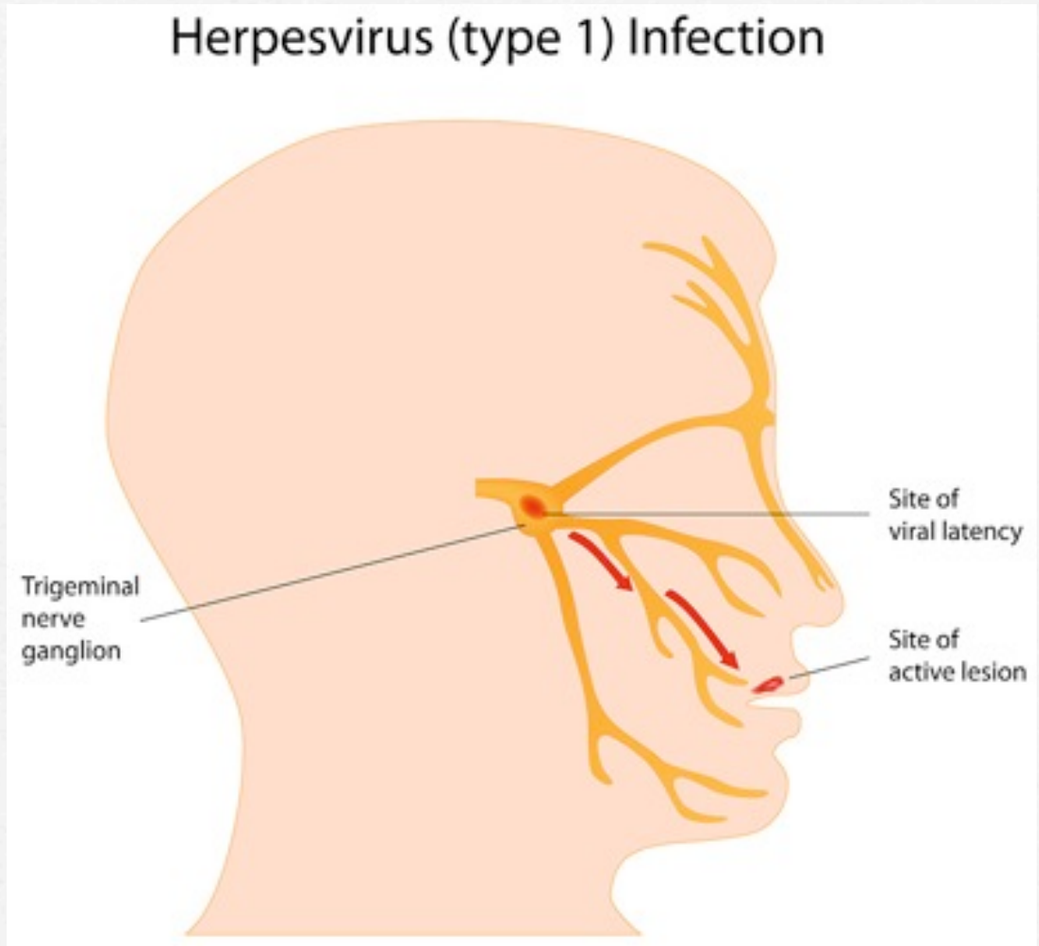
Latency

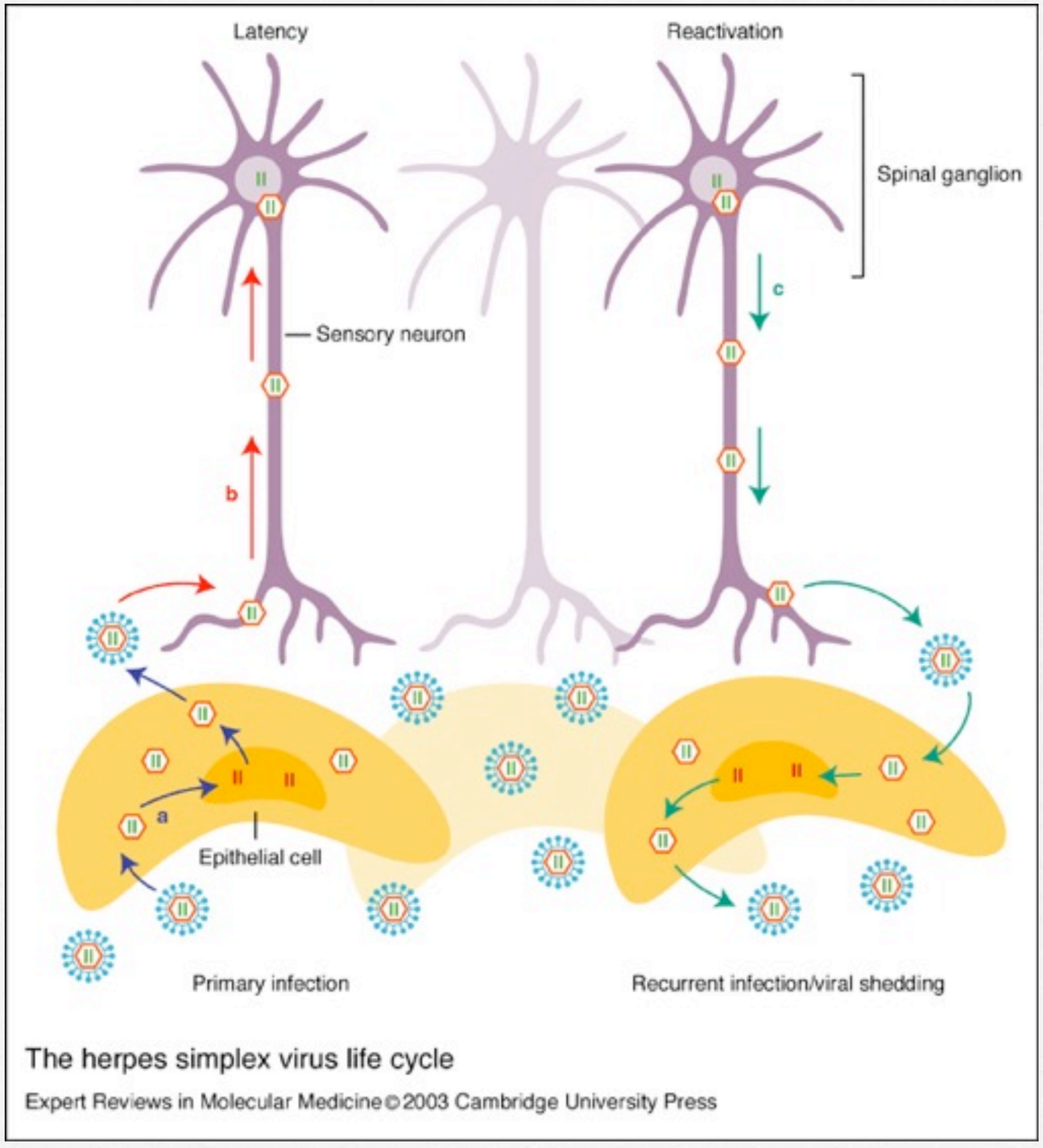
- **<u>Herpes viruses:</u> simplex** (STD and cold sores)**, zoster** (chickenpox)**, Epstein-Barr** (mononucleosis)
  - **herpes virus remains quiescent in nerve cells**
  - nerve cells carry few MHC molecules which makes it harder for T cells to recognize infected cells and attack them
  - when conditions are favorable the virus reactivates and move down the neuron to infect epithelia cells
    - (simplex reactivate frequently but zoster usually only once)

? Why do nerve cells have few MHC molecules?

Nerve cells are amitotic (you can make more of them) so they do not want the immune system to kill them because the destroyed nerve cells can be replaced. It is if they would rather be re-infected over and over again instead of being killed

Herpes Infection, Latency & Reactivation





The herpes simplex virus life cycle

Attack the Immune System

- **Pathogens can suppress the immune system or even attack it directly.**

- Bacterial Example: *Staphylococcal* bacteria

  - these bacteria produce toxins that act as ***superantigens***, these toxins bind to receptors differently and result in massive release of cytokines which causes systemic inflammation that is life threatening by itself and it suppresses the immune system

- Viral Example: *HIV*

  - **the HIV virus attacks T cells and macrophages directly** both of which are critical to normal immune function

*More Defenses Against Immune Systems

- **Specialized Defenses**
- Bacterial Example: *Mycobacterium tuberculosis*, is eaten by macrophages but **can prevent the fusion with the lysosome so it is not digested**
  - In fact macrophages are their primary host!
- Bacterial Example: *Listeria monocytogenes*, is eaten by macrophages, **escapes from vesicle** and then begins to multiply, eventually spreading to nearby cells with unique mechanism that avoids extracellular detection.
  - Results in a type of food poisoning that kills 20-30% of clinical infections

*More Defenses Against Immune Systems

- **Specialized Defenses**
- Bacterial Example: *Borrelia burgdorferi*
  - Causes Lyme Disease!
- Bacterial Example: *Treponema pallidium*
  - Responsible for the STD syphilis!
- **Both avoid recognition by antibodies by coating their surface with host molecules until it reaches the target tissues.**

*More Defenses Against Immune Systems

- **Specialized Defenses**
- Viral Examples:
- Viruses had wide range of defensive strategies.
  - **capture host's genes responsible for making cytokines or cytokine receptors**
  - **inhibit assembly or synthesis of MHC molecules**

*Pathogenic Defenses

- **Specialized Defenses**
- Protistan Example *Toxoplasma gondii:*
  - **Generates it own vesicle that does fuse with any other cellular/host vesicle, thereby becoming invisible to the immune system.**
    - carried by endotherms but mainly cats, 1/3 people worldwide carry the parasite
    - contract it from under cooked meat or feline feces
    - Been implicated in human suicidal behaviors

A Final Point

- **Bacterial Defenses**
  - **Bacteria also produce antifungal compounds and antiobiotics.**
    - Antifungal compounds protect against fungal attack
      - *Leafcutter ants cultivate a fungus to help them digest cellulose from the leaves they cut and to keep other fungi from attacking the cultivated fungus they coat themselves with bacteria that produce half of all known antibiotics!*
    - Antibiotics obviously kill other bacteria which may have a defensive component but it probably helps the bacteria compete against other bacteria for limited resources

Leafcutter Ants- First Farmers