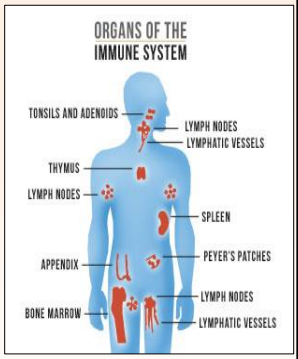
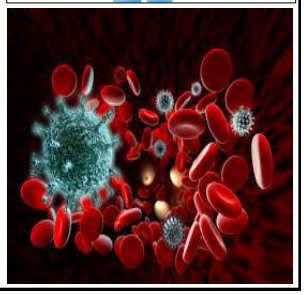
Ch. 11: Immune Physiology

Objectives:

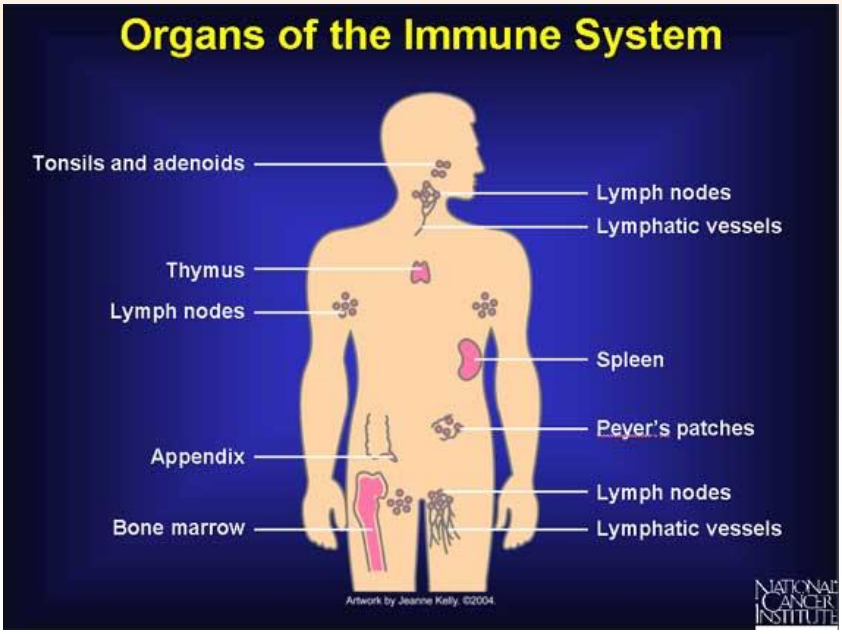
1. Review immune organs & cells.
2. Two categories of immunity: innate vs adaptive
3. Understand functions of adaptive immunity cells (T-cells and B-cells)
4. Natural vs artificial immunity
4. Understand autoimmunity disorders.





1

1. *Review* Immune Organs & Cells.



2

1. *Review* Immune Organs & Cells. Pg 164 Wiki text

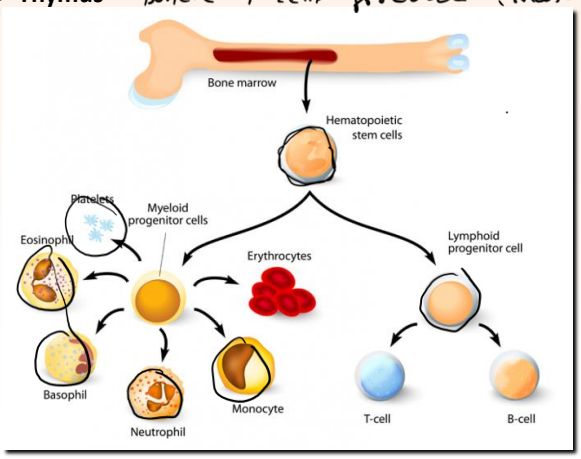
Immune system = The cells & organs that defend gainst pathogens & cancer.

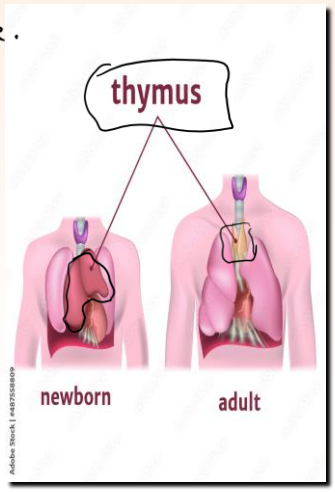
1) Lymph Organs:

A. *Primary lymph organs* = *where lymphocytes develop & mature*

> **Bone marrow** - produces WBCs, RBCs, platelets

> **Thymus** – where T-cells produced & mature.





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1. *Review* Immune Organs & Cells. Pg 164 Wiki text

Immune system = The cells & organs that defend gainst pathogens & cancer.

1) Lymph Organs:

A. *Primary lymph organs*

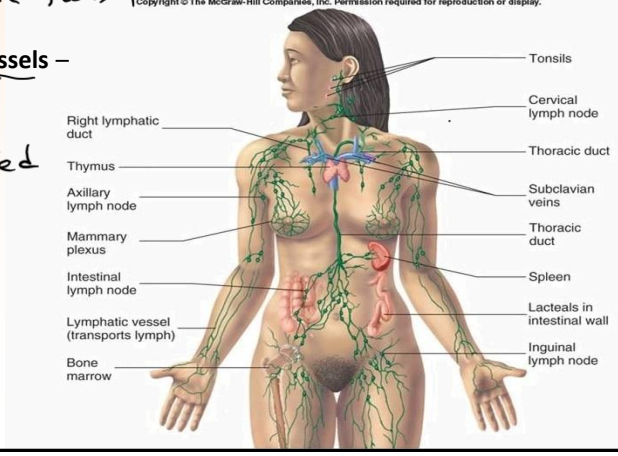
filter lymph fluid.

B. *Secondary lymph organs.* = *where immune responses are initiated.*

> **Lymph nodes** – where T cells & B cells live. B cells make antibodies,

> **Lymphatic & blood vessels** –

return leaked fluid from circulatory system.



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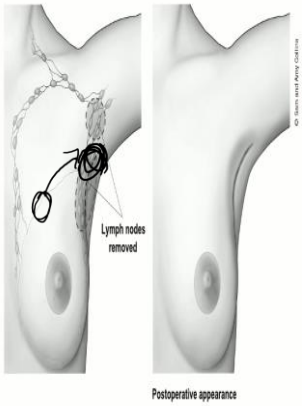
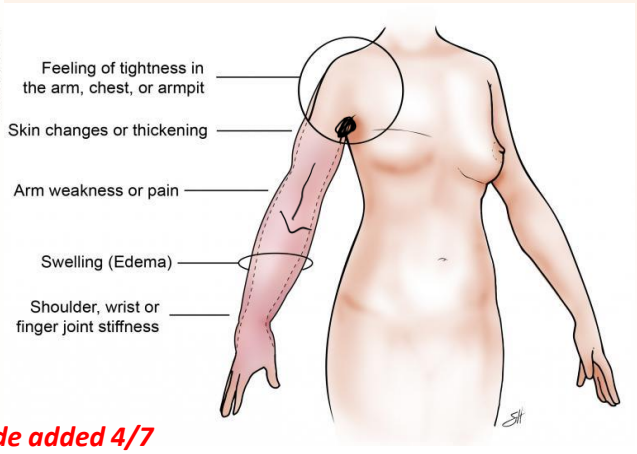
Lymph nodes and fluid collection. When lymph nodes removed, fluid buildup or ***lymphedema*** can occur.

Do NOT take blood pressure from arm of someone who had axillary lymph nodes removed – can cause lymphedema!



Axillary lymph node dissection



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1. *Review* Immune Organs & Cells. Pg 164 Wiki text

Immune system = The cells & organs that defend gainst pathogens & cancer.

1) Lymph Organs:

A. *Primary lymph organs*

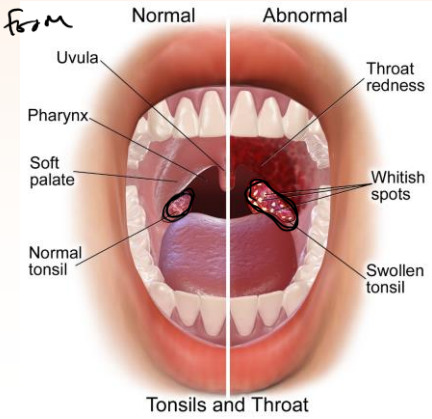
B. *Secondary lymph organs.* = *where immune responses are initiated.*

> **Lymph nodes** –

> **Lymphatic & blood vessels** –

> **Tonsils** - provide immune protection from things inhaled or eaten.

> **Spleen** – Filters blood.



Tonsils and Throat

6

1. *Review* Immune Organs & Cells. Pg 164 Wiki text

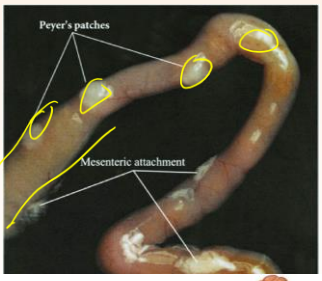
Immune system = The cells & organs that defend gainst pathogens & cancer.

1) Lymph Organs:

A. *Primary lymph organs*

B. *Secondary lymph organs.* = *where immune responses are initiated.*

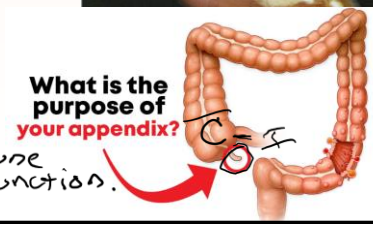
> Lymph nodes –
> Lymphatic & blood vessels –
> Tonsils -
> Spleen –



> **Intestines** – have peyers patches to protect from ingested pathogens.

> **Appendix** - immune function at start of large intestine (colon)

> **Liver** - filters toxins from blood. Has Kupffer cells have immune Function.



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1. *Review* Immune Organs & Cells. Pg 164 Wiki text

Immune system = The cells & organs that defend gainst pathogens & cancer.

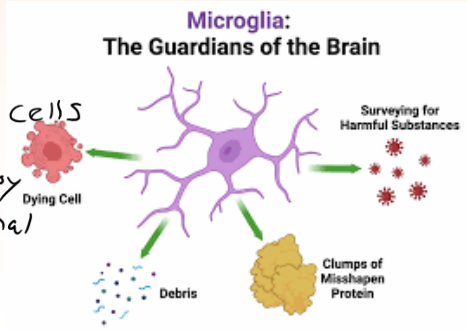
1) Lymph Organs:

A. *Primary lymph organs*

B. *Secondary lymph organs.* = *where immune responses are initiated.*

> Lymph nodes –
> Lymphatic & blood vessels –
> Tonsils -
> Spleen –
> Intestines –
> Appendix
> Liver

> **Brain** – ~~has~~ has microglia cells that seek out & destroy pathogens or abnormal tissue



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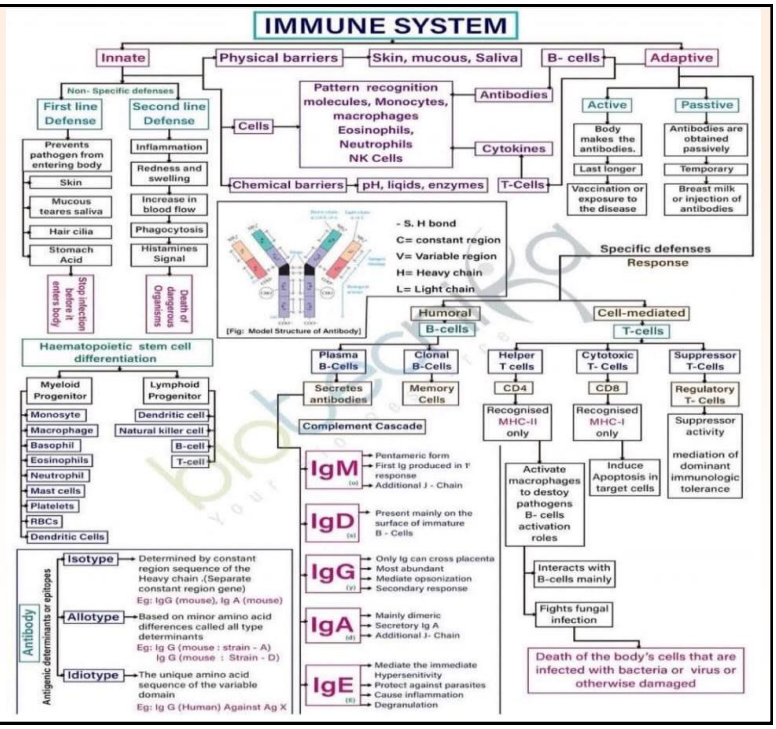
How complex is our immune system?



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We will be simplifying it a bit …

You will be able to study this chapter with the aid of some flow diagram:

Click **HERE** for sequence of immune response starting with a pathogen gaining entry into your body, from innate immune response to adaptive immune response.

Click **HERE** for the outline of the innate immune system (including external and internal innnate response) and the adaptive immune response (t-cells and b-cells).

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3 Lines of Defense from Pathogens! Pg 162 Wiki text

Innate

A) External Innate Immunity (non-specific)

Barriers to keep pathogens out.

B) Internal Innate Immunity (non-specific)

Internal protection when pathogen enters body

Adaptive

Adaptive or Acquired Immunity (specific) humoral

Immunity specific to pathogens.

T-cells & B-cells

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1) Innate Immunity (non-specific)

A. External Innate Defense (barriers to keep things OUT of your body)

- **Epithelial membranes**
  > skin
  > sweat – is antimicrobial
- **Stomach acid –** antimicrobial
- **Respiratory tract –** tonsils
  – alveolar macrophages (big eat)
- **Urinary / genital defense =** urethra acidic, vagina acidic
- **Eyes -** tears are antimicrobial

immune cells that ingest & destroy pathogens

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1) Innate Immunity (non-specific)

high body temp kills

B. Internal innate defense (if things get in, try & kill them without antibodies)

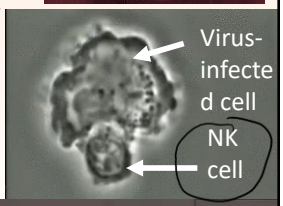
bacteria

Step 1. Phagocytic WBC Cell response

> Neutrophils & Monocytes in blood — macrophages that can consume & destroy pathogens

> WBCs secrete **endogenous pyrogens** (within) — resets hypothalamus temp. limit to allow fever (free)

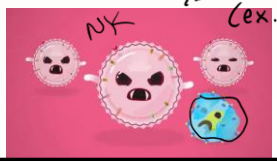
> WBCs secrete **cytokines & chemokines** - help to alert



Step 2. Natural killer (NK) cells

> secrete **interferons** — chemicals that kill viruses

> **toxic granules** — destroys abnormal cells (ex. tumor cells)



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1) Innate Immunity (non-specific)

B. Internal innate defense (if things get in, try & kill them without antibodies)

Step 1. Phagocytic WBC Cell response.

> Neutrophils & Monocytes in blood attack, engulf, & kill pathogens

> WBCs secrete **endogenous pyrogens** to cause **fever response.**

> WBCs secrete chemical cries for help (**cytokines & chemokines**)

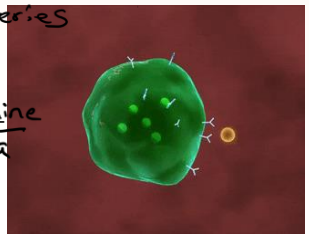
causes inflammation
- red itchy watery eyes
- runny nose
- reddened skin
- ↑ temp at site
- bronchoconstriction
- vasodilation of arteries

Step 2. Natural killer (NK) cells

> secrete **interferons** to kill viruses.

> **toxic granules** to kill tumor/cancer cells.

Mast cell secreting histamine



Step 3. Inflammatory response

> **Mast cells** – (a.k.a. basophils) secrete histamine

> **Complement proteins** – poke holes in bacteria to lyse them.

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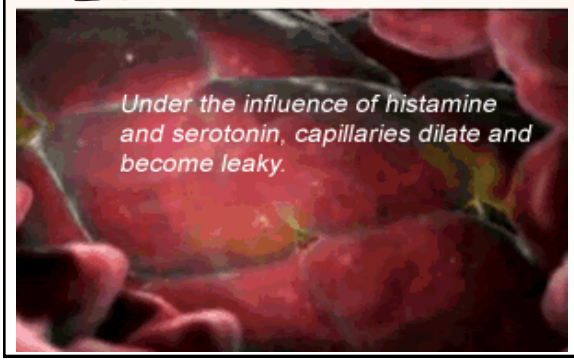
Step 1: Phagocytic WBC response:

1. In bloodstream - **Neutrophils** & **Monocytes** **are phagocytes** that destroy pathogens & secrete endogenous pyrogens (cause fever).

2. Histamine secreted by mast (basophil) cells makes blood vessels "leaky" so WBC can escape, especially **monocytes** which "**extravasate**" out of capillary into tissues.

exterior vessel



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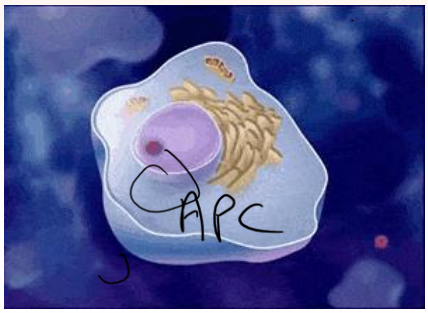
Step 1: Phagocytic WBC response:

3. Monocytes migrate from blood into tissues by ***extravasation*** to become Macrophage that destroy pathogens in tissue.

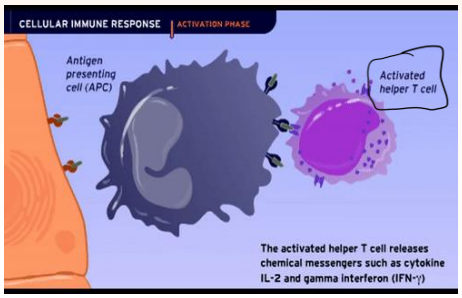
4. Macrophages places pathogen's antigen it cell surface – now macrophage is called an Antigen-Presenting Cell **(APC).**

APCs will activate Helper T-cells ***(see later in notes)***

- Phagocytes then send chemical "Cries for help" = **cytokines, chemokines**



A macrophage becoming an APC



An APC activating a helper T-cell

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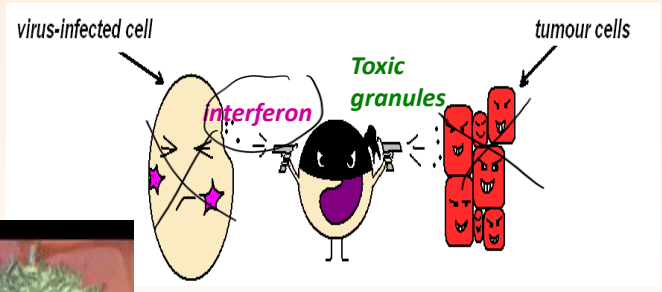
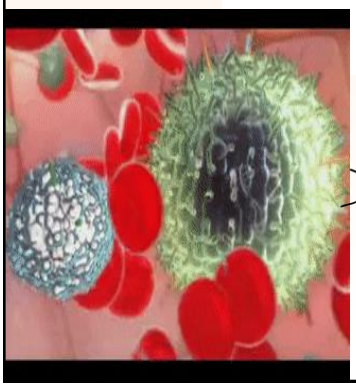
Step 2. Natural Killer (NK) Cell response

- are activated by cries for help (cytokines, chemokines)
- release interferon to kill virus-infected cells.
- release toxic granules to kill tumor cells.





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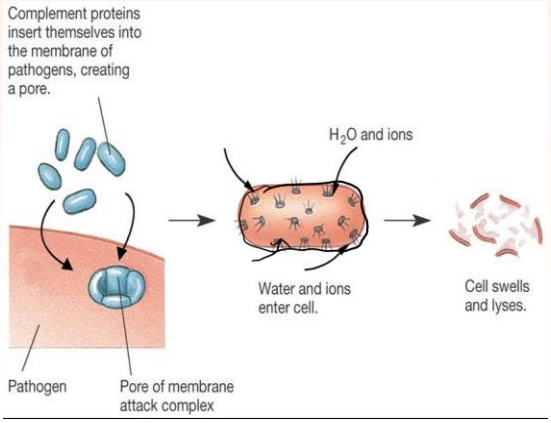
Step 3. Inflammatory Response

- **Mast cells** – secrete **histamine** for inflammation. Causes vasodilation of blood vessels. (Allows more WBCs to enter into tissue as macrophages!)

- **Complement proteins** - kill bacteria by making holes in them (bacteria burst!) & cause inflammation.



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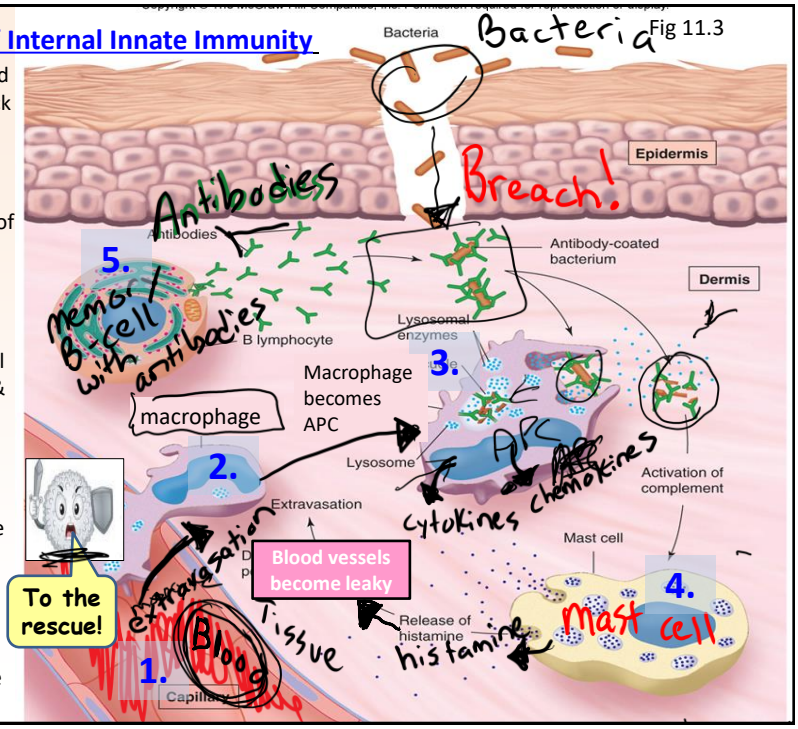
Activation of Internal Innate Immunity

Fig 11.3

1. Neutrophil and monocytes attack pathogen in blood, secrete pyrogens (fever)
2. Extravasation of monocyte in tissue
3. macrophages eat pathogen, become **APC** (will activate T-cells, & cry for help (cytokines & chemokines)
4. Mast cells release histamine (start redness & swelling)
5. Cytokines & chemokines call cells of adaptive immunity



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Review

> Review of Immune Organs and Cells

> Innate Immunity (2 types)

External innate immunity (keep pathogens OUT)
Internal innate immunity (activate when pathogens get in)

> <u>Activation of Internal Innate immunity</u>

- **Neutrophils & monocytes** (phagocytic cells in blood that attack pathogens)
  - > secrete endogenous pyrogens (fever)
  - > secrete chemical cries for help (cytokines & chemokines)
- **Phagocytic cells in tissue** (macrophages, which become APC)
- **Natural killer (NK) cells**
  - > interferon to kill viruses & toxic granules to kill tumor cells
- **Mast cells**
  - > secrete histamine for inflammation response (edema, redness, pain, vasodilation)
- **Complement proteins**
  - > poke holes in bacteria to lyse them

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Activation of Adaptive Immunity – or long term specific defenses

Adaptive immunity:

The link between innate immunity & adaptive immunity is APCs & helper T-cells.

Provided by lymphocytes

> Are produced in bone marrow

> T-lymphocytes (**T-cells**) & B-lymphocytes (**B-cells**)

> T-cells mature in **thymus**.

- Are involved in **Cell-Mediated Immunity** (T-cell immunity)
- T-cells must activate first in order to activate B-cells

> B-cells mature in lymph nodes & spleen, and produce **antibodies**.

- Are involved in **Antibody-Mediated Immunity**

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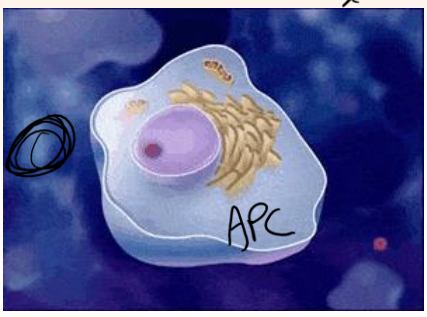
How do T-cells get "activated"?

By Antigen-Presenting Cells (APCs) of the internal innate immunity

- APC presents antigen to Helper T-cells
- Helper T-cell then is ACTIVATED! Then helper T-cells tell other T-cells, and B-cells what to do.



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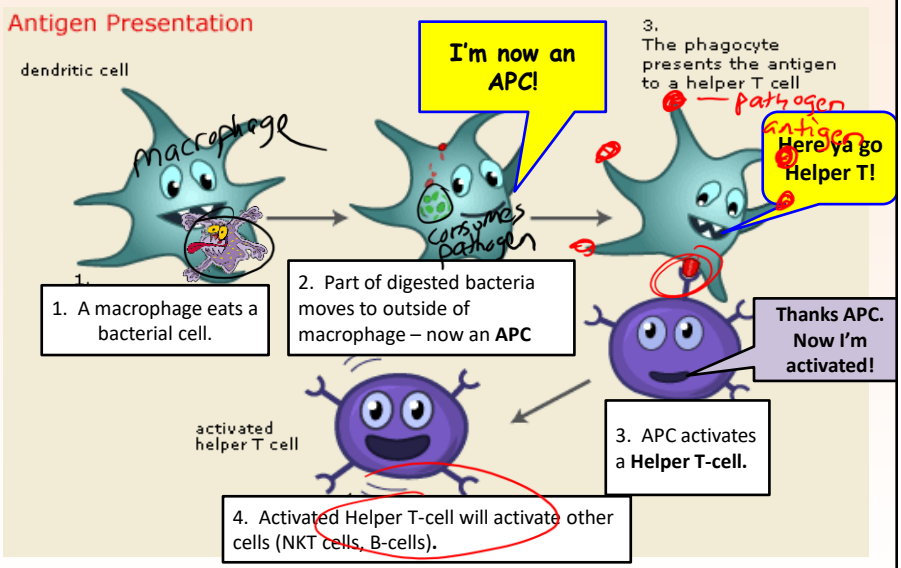

Tissue **macrophages** engulf pathogen. *Part of pathogen moves to outside of macrophage – now an **antigen-presenting cell (APC)**, and APC then activates **Helper T-cells**.*

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Two types of Adaptive Immunity:

1. Cell-Mediated Immunity (T-cells!)

•**Helper T-cells** (activated by APCs)
Now activates other T-cells:

> Cytotoxic T cells (T_C)
- Kill pathogen on contact

> Memory T cells (T_M)
- T-cells retain memory of pathogen

> Regulatory T-cells (T_{reg})
– inhibit T_C and B cells.
– may guard against allergies & autoimmune disease.

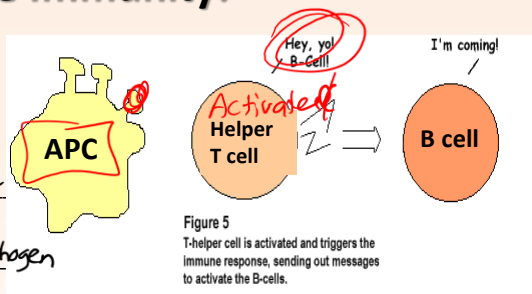

Figure 5
T-helper cell is activated and triggers the immune response, sending out messages to activate the B-cells.

• **Helper T-cells** activate **B-cells** to make antibodies.

2. Antibody-Mediated Immunity (B-cells)

•**B-cells** are activated by Helper T-cells) & make **antibodies** (or immunoglobulins) specific to the pathogen.

•Results in formation 2 types of B-cells
> Plasma B-cells – ready to fight immediately
> Memory B-cells – wait in lymph nodes for future exposures

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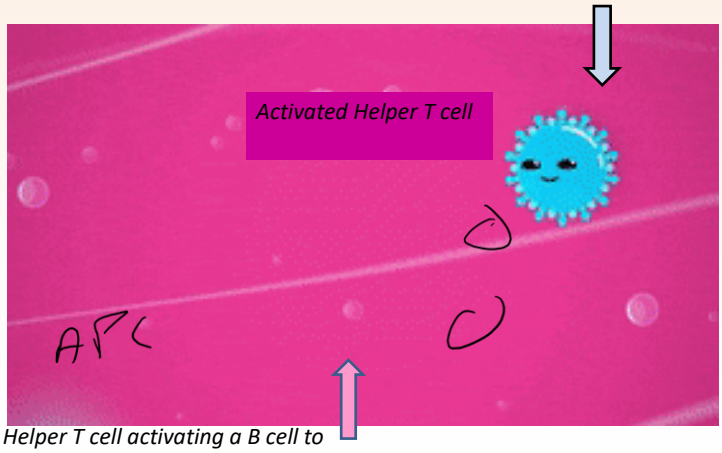
Activated T-cells stimulate **B-cells (plasma cells)** to make **antibodies** to an antigen**.**



Helper T cell activating a B cell to make antibodies specific to pathogen

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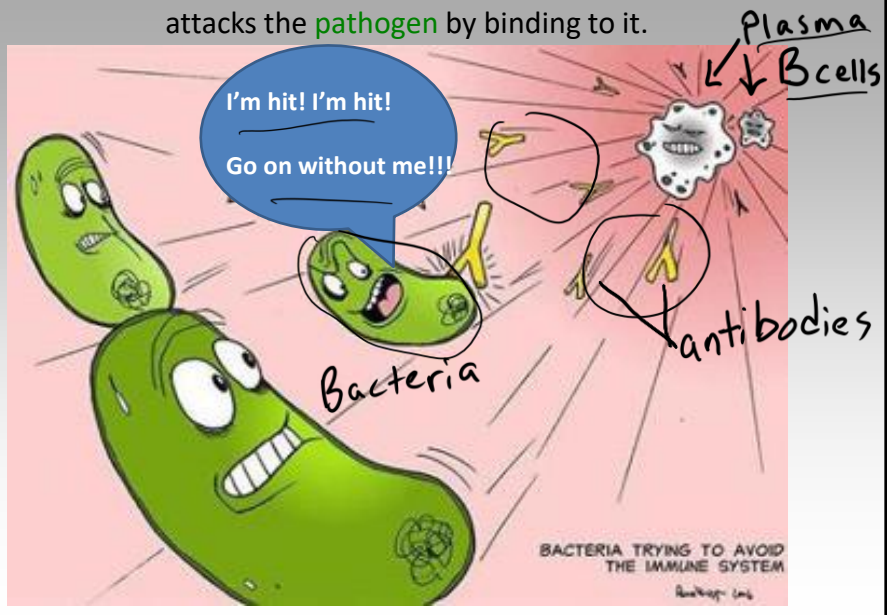
Plasma B-cell (the white blobs) with antibodies (the yellow **Y**'s), attacks the pathogen by binding to it.



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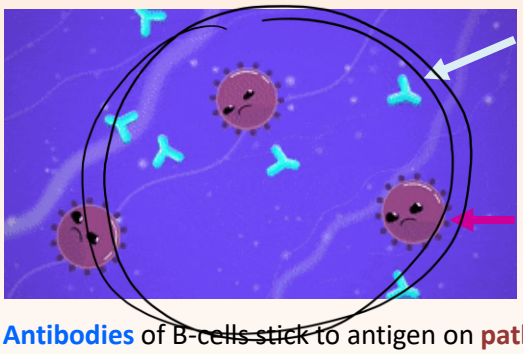
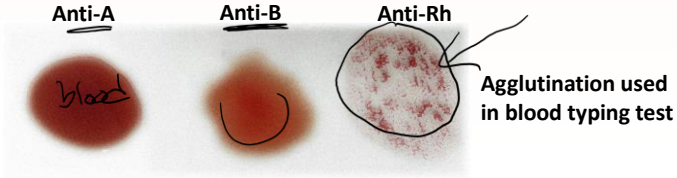


Antibodies of B-~~cells stick~~ to antigen on **pathogen cells** and "stick them together" – process called **agglutination.**

The agglutinated blob will attract macrophages, which will engulf the blob & destroy it.



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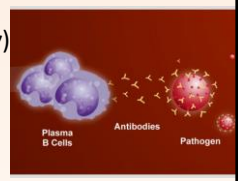
More about B-Cells

> Activated by stimulation by activated Helper T-cells.

> produce **antibodies (immunoglobulins)** to specific antigens.
> Provides ***humoral (or antibody-mediated, or specific immunity)***

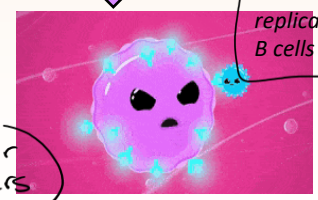


> Exposure of B-cell to its specific antigen causes release of antibodies to bind to antigens.

> causes clonal production of 2 types B-cells with antibodies:

A) **plasma B cells** ready to fight now

B) **memory B cells** wait in lymph nodes to fight later (in large numbers)



Clonal replication of B cells

Effects of antibodies:

- ~~Activate complement proteins~~
- Clonal replication of B-cells (↑ their numbers)
- Agglutination reaction (antibodies sticks antigen-bearing cells together) "tags" pathogenic cells so they're recognized & destroyed by phagocytes.

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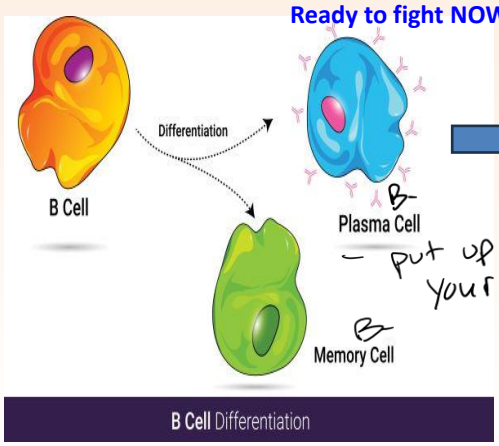
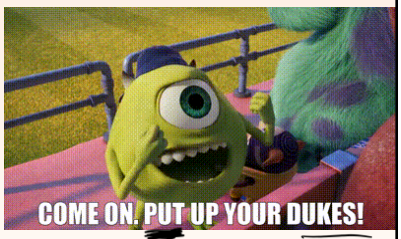
Ready to fight NOW





– put up your dukes – fight now

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Action of B Lymphocytes

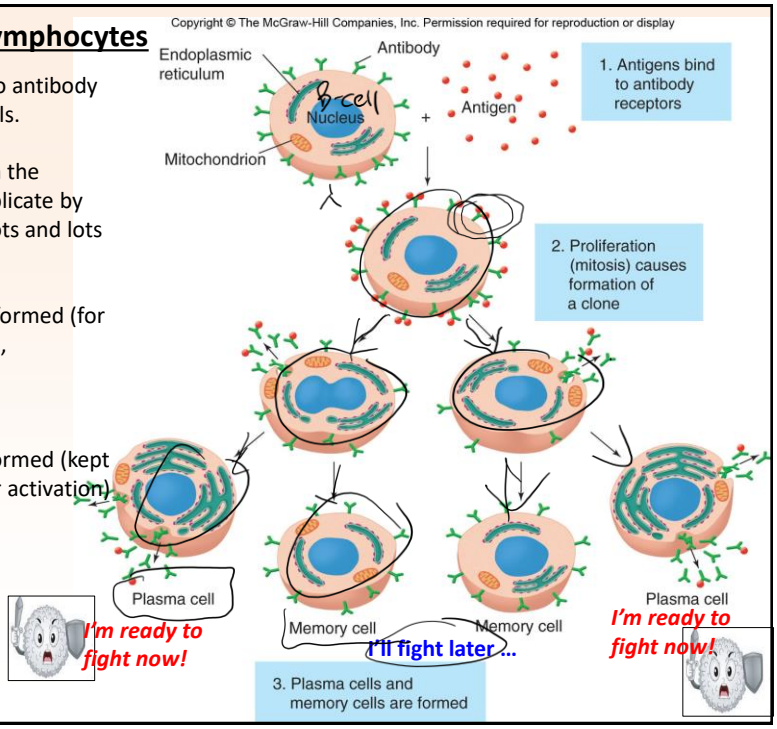
1. Antigen binds to antibody receptors on B-cells.

2. On contact with the antigen B-cells replicate by **cloning** to make lots and lots more B-cells.

3. Plasma B-cells formed (for immediate action),

and

Memory B-cells formed (kept in storage for later activation).



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Sequence of events, from entry of pathogen into the body to the formation of antibodies:

1. Bacteria enters tissue from a break in skin.
2. neutrophils & monocytes = Phagocytic non-specific WBC in the blood stream.
3. monocytes Cell that extravasates from blood vessel into tissue. (is now called an macrophage)
4. APC = Phagocytic cell in tissue, which finds pathogen, kills it, and puts antigen on its surface.
5. Helper T cell = Cell of cell-mediated adaptive immunity, which becomes activated by interaction with the cell in #4 above.
6. Activated cell from #5 above can now activate these cells:
   - A. Cytotoxic T-cell = Cell of cell-mediated adaptive immunity, which directly kills pathogen.
   - B. Memory T-cell = Cell of cell-mediated adapted immunity, which keeps a memory of pathogen.
   - C. B cells = Cell that is part of antibody-mediated adaptive immunity)
7. Cell from 6C above can make antibodies (otherwise known as immunoglobulins)
8. Cell from 6C above encounters its pathogen and the following happens:
   - A. Clonal replication of B-cells
   - B. Agglutination (antibodies stick to cells w/antigen)

Click **HERE** for blank flow diagram.

Click **HERE** for KEY

2-3 weeks

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CATEGORIES OF IMMUNITY:

Innate Immunity (also called _____) Vs Adaptive Immunity (also called _____)

1) _____ 2) _____ 1) _____ 2) _____

Click **HERE** for blank flow diagram of immune categories

Click **HERE** for KEY

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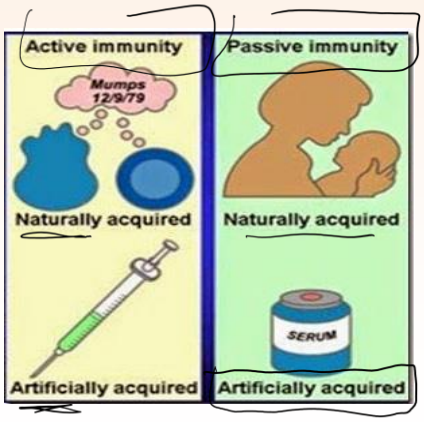
Classification of Immunity

antibodies (work)

1) Active immunity = get immunity (antibodies) that you produce from actual exposure (natural) to disease organism or from vaccination (artificial exposure).

given antibodies (no work)

2) Passive Immunity = get immunity (antibodies) from source outside your body: Natural (breast milk) or artificial (injection of antibodies).



Active Immunity

- **Active natural immunity** - make antibodies after exposure to sick person
- **Active artificial immunity** - make antibodies after vaccination

Passive Immunity

- **Passive natural immunity** - Breast milk.
- **Passive artificial immunity** - given injection of antibodies

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4. Autoimmunity Disorders

Problems with the Immune Response

autoimmunity – when immune cells attack self; can be B or T cells.

*** Abnormal T-cells from Thymus associated with most autoimmune disorders!

Ex. Of autoimmune disorders we've covered:

> *rheumatoid arthritis* – attack on connective tissue of synovial joints.

> *rheumatic heart disease* – antibodies produced from strep throat attack heart valves.

> *multiple sclerosis* – attacks myelin sheaths on neurons.

> *Grave's disease* – attack on thyroid gland TSH receptor.

> *Myasthenia gravis* – destruction of nicotinic cholinergic receptors on skeletal muscles.

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Review

Adaptive Immunity
- Cell-mediated adaptive immunity
- Antibody-mediated adaptive immunity

Types of T and B Cells
- T-cell formation and activity
- T_H, T_C, and T_{reg}
- B-cell formation and activity

Classification of Immunity (active vs passive)

Autoimmune Disorders

End of immune material!

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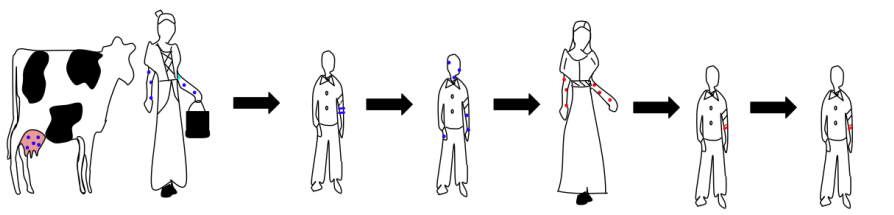
Vaccinations

- Late 1700s → Edward Jenner noticed milkmaids rarely had smallpox.
- Jenner reasoned that milkmaids were immune to smallpox because they had been exposed to cowpox.
- To test his hypothesis, he inoculated a boy with cowpox pathogens and then with smallpox pathogens. As predicted, the boy did not contract smallpox.



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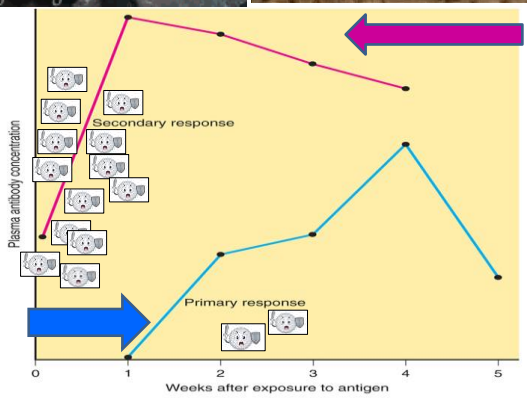
vaccination → 1° immune response → memory cells

Primary response: takes ~ 2 weeks for good production of plasma B-cells with antibodies (**high antibody titer,**) and memory B-cells after 1st exposure.



Secondary response: have lots of memory B-cells that were stored & waiting for future exposure = **stronger, faster immune response!**

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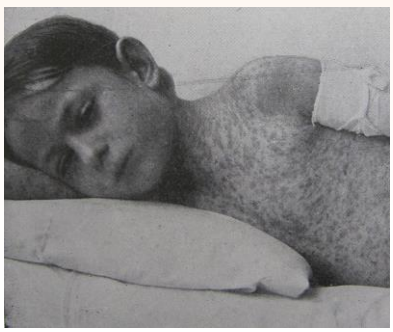
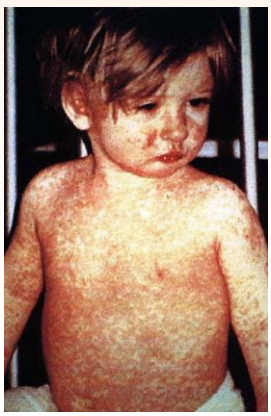
Vaccinations and Halt of Communicable Disease: THE SCIENCE

Example of Vaccine Effectiveness:

In the United States, before measles vaccine became available in the mid-1960s was estimated over 530,000 cases with 500 deaths per year. After vaccine – has been **99.9% decrease** in incidence of the disease.





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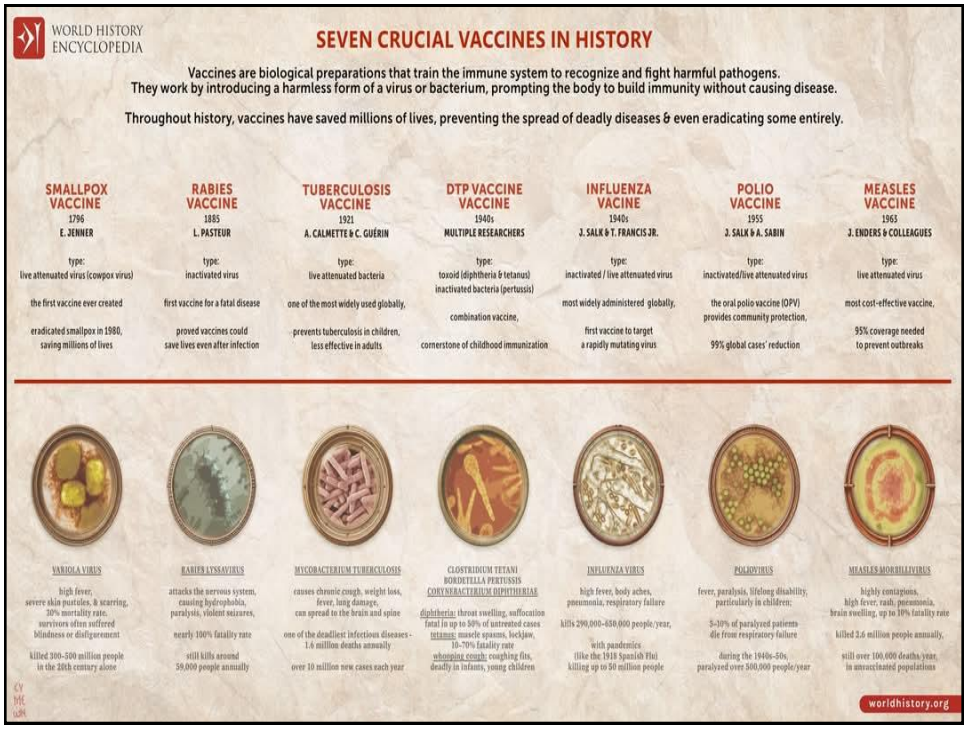

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Vaccinations and Halt of Communicable Disease: THE SCIENCE

DISEASE	PRE-VACCINE ERA ESTIMATED ANNUAL MORBIDITY*	MOST RECENT REPORTS OR ESTIMATES† OF U.S. CASES	PERCENT DECREASE
Diphtheria	21,053	0†	100%
H. influenzae (invasive, <5 years of age)	20,000	31‡	>99%
Hepatitis A	117,333	2,890§	98%
Hepatitis B (acute)	66,232	18,800§	72%
Measles	530,217	187†	>99%
Mumps	162,344	584†	>99%
Pertussis	200,752	28,639†	86%
Pneumococcal disease (invasive, <5 years of age)	16,069	1,900‡‡	88%
Polio (paralytic)	16,316	1†	>99%
Rotavirus (hospitalizations, <3 years of age)	62,500**	12,500††	80%
Rubella	47,745	9†	>99%
Congenital Rubella Syndrome	152	1†	99%
Smallpox	29,005	0†	100%
Tetanus	580	26†	96%
Varicella	4,085,120	167,490§§	96%

http://www.immunize.org/catg.d/p4037.pdf

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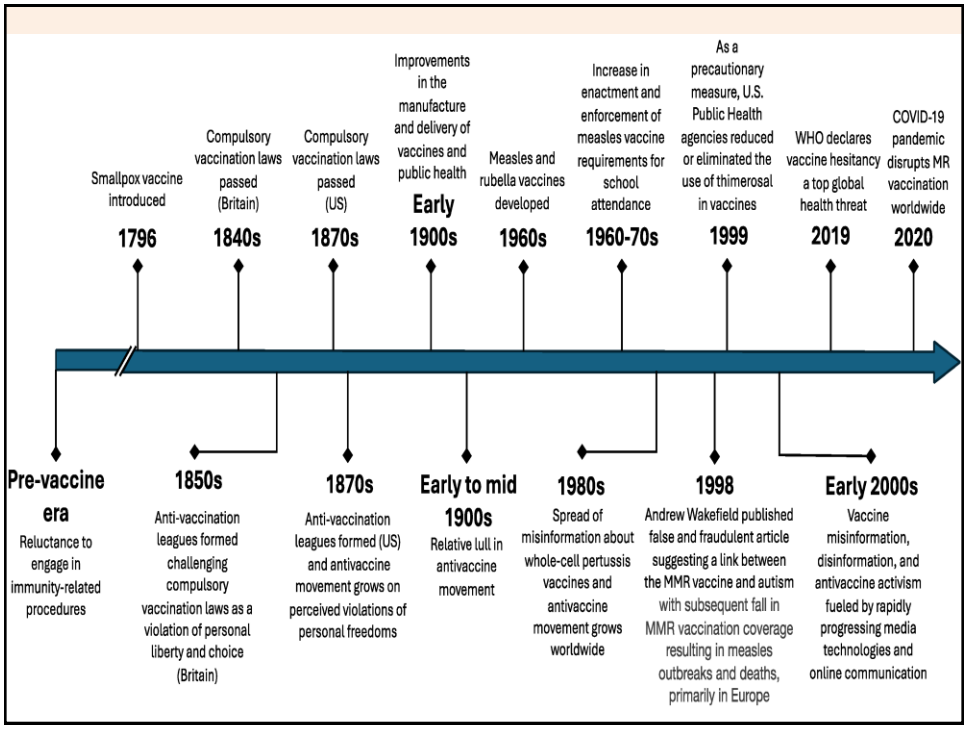

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Vaccinations and Halt of Communicable Disease: THE CONTROVERSY

Do vaccinations cause Autism????

NO!

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Vaccinations and Halt of Communicable Disease: THE CONTROVERSY

Where did the controversy start?

A study originally published in journal ***Lancet*** by **Andrew Wakefield in 1995** claimed that his study of **12 children** showed that the 3 MMR (measles, mumps, rubella) vaccines taken together (1st at 1 year, then at 5 -6 yrs) could alter immune systems, causing intestinal woes that then reach, and damage, the brain (autism?)

Scientific community responded:

> Dozens of epidemiological studies found no merit to his work
> His claims were based on a tiny sample size.
> The British Medical Journal called his research "fraudulent."
> The British journal ***Lancet*** retracted his publication.
> The British medical authorities stripped him of his license.

Problem:

People still believe Wakefield. Groups of people began to NOT vaccinate their children.

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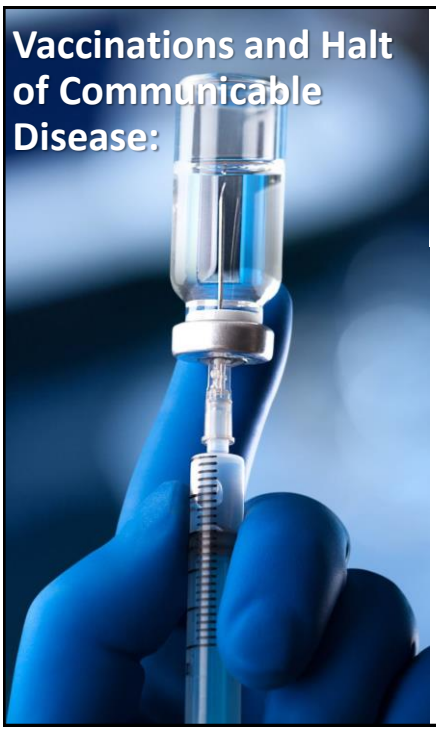

- Nationwide, vaccination rate against diseases has stayed at 90 % or higher, but % in some of the country now well below that, making those communities more vulnerable to disease outbreak.

- There has been an increase in cases of **Measles in the US** – especially in counties where vaccination rate below 90%.

- Medical doctors & epidemiology experts say that vaccination rate of ~95 % needed to protect a community by "herd immunity".

Herd immunity = indirect protection from infectious disease when a large % of population has become immune (natural or vaccination-acquired) it reduces potential exposure of non-immune people (aren't or can't be vaccinated) to that disease.

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New Secretary of the U.S. Department of Health and Human Services: RFK Jr. (Feb 2025)

How bad is this??

BAD *(he has long been an anti-vaxxer)*

> Recommended giving vitamin A to treat measles in children. Vitamin A is stored in the liver, and high levels are toxic and can lead to liver damage.

https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(24)02603-5/fulltext

https://edition.cnn.com/2025/03/05/health/measles-rfk-vitamin-a-misinformation/index.html

https://www.cnn.com/2025/03/26/health/texas-measles-vitamin-a-toxicity/index.html

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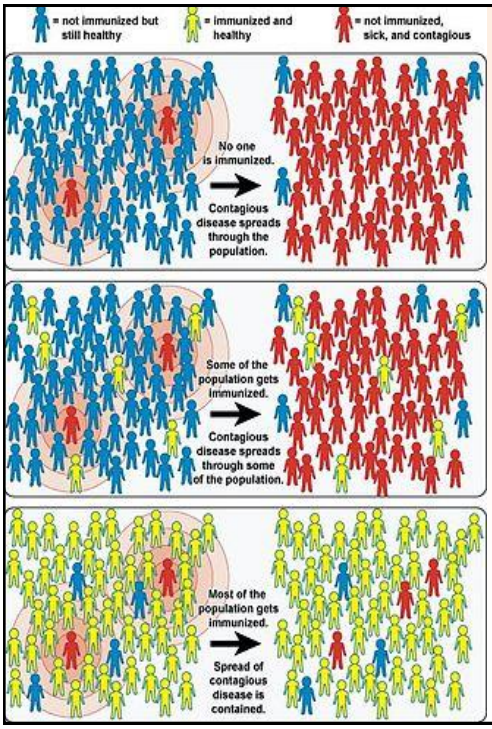

Herd Immunity

The **top box** shows an outbreak in a community in which a **few people are infected (shown in red)** and **the rest are healthy but unimmunized (shown in blue);** the illness spreads freely through the population.

The **middle box** shows a population where **a small number have been immunized (shown in yellow)**; those not immunized become infected while those immunized do not.

In the **bottom box**, a large proportion of the population have been immunized (yellow); this prevents the illness from spreading significantly, including to unimmunized people.

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Review

Vaccination

- History of vaccination
- Action of vaccinations on immunity
- Controversy on vaccinations
- *[There shouldn't be!!! – Vaccines work!]*

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