EPIDEMIOLOGY (MCB 404)

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Introduction

- Epidemiology is the study of the distribution and determinants of health-related states or events in specified populations and the application of this study to control health problems.
- It's a fundamental field within public health, focusing on understanding the patterns, causes, and effects of health and disease conditions in populations.
- The study helps in diagnostic purposes and provision of information on aetiology

Introduction

- The primary goal of epidemiology is to improve public health outcomes by identifying the causes of diseases and health-related events and implementing interventions to prevent or control them.
- Epidemiologists seek to understand why certain diseases are more prevalent in some populations than others and how various factors, such as genetics, behavior, environment, and social factors, contribute to health outcomes.
- Epidemiologists use a variety of research methods to investigate patterns and determinants of health and disease.
- These methods include surveillance (monitoring and reporting of diseases and health events), observational studies (such as cohort studies and case-control studies), and experimental studies (like randomized controlled trials).

Epidemiological terms

- Sporadic disease: when a disease occurs occasionally and at irregular intervals in a human population e.g bacterial meningitis
- Endemic: an occurrence of disease at a steady low level frequency within a specific population
- Epidemic: an outbreak of disease affecting many people at once.
- Pandemic: an increase in disease occurrence within a large population over a very wide region usually the world at large
- Morbidity rate: measures the numbe of individuals thet becomes ill due to a specific disease within a susceptible population during a specific time interval
- Prevalence rate: the number of individuals infected in a population at any time no matter when the disease began.
- Mortality rate: measures the number of individuals that die due to a specific disease within a specified time interval.
- Incubation period : the period between infection and onset of signs and symptoms
- Window period: the period between infection and when lab diagnosis can detect the infection.

Statistical applications in epidemiology

- Frequency distribution:
- Ratio/rate/proportion
- Prevalence
- Incidence
- Measure of central tendency: mean, median and mode
- Measure of dispersion: Standard deviation, variance, co-efficient of dispersion, standard error mean

Frequency distribution

- The frequency distribution is a table which displays how many people fall into each category of a variable such as age, income level, or disease status.

Frequency distribution

Neonatal listeriosis, General Hospital A, Costa Rica, 1989

ID	Sex	Culture Date	Symptom Date	DOB	Delivery Type	Delivery Site	Outcome	Admitting Symptoms
CS	F	6/2	6/2	6/2	vaginal	Del rm	Lived	dyspnea
CT	M	6/8	6/2	6/2	c-section	Oper rm	Lived	fever
WG	F	6/15	6/15	6/8	vaginal	Emer rm	Died	dyspnea
PA	F	6/15	6/12	6/8	vaginal	Del rm	Lived	fever
SA	F	6/15	6/15	6/11	c-section	Oper rm	Lived	pneumonia
HP	F	6/22	6/20	6/14	c-section	Oper rm	Lived	fever
SS	M	6/22	6/21	6/14	vaginal	Del rm	Lived	fever
JB	F	6/22	6/18	6/15	c-section	Oper rm	Lived	fever
BS	M	6/22	6/20	6/15	c-section	Oper rm	Lived	pneumonia
JG	M	6/23	6/19	6/16	forceps	Del rm	Lived	fever
NC	M	7/21	7/21	7/21	vaginal	Del rm	Died	dyspnea

Source: 11

Abbreviations

vaginal = vaginal delivery
Del rm = delivery room
Oper rm = operating room
Emer rm = emergency room

Ratio, proportion, rate

- Ratio, proportion, rate = x/y × 10n
- . 10n is read as "10 to the nth power." The size of 10n may equal 1, 10, 100, 1000 and so on depending upon the value of n. For example, 100 = 1 101 = 10 102 = 10 × 10 = 100 103 = 10 × 10 × 10 = 1000
- In a ratio, the values of x and y may be completely independent, or x may be included in y.
- A proportion is a ratio in which x is included in y.
- Rate, is often a proportion, with an added dimension: it measures the occurrence of an event in a population over time.
- The basic formula for a rate is as follows:
- Rate = $\frac{\text{(number of cases or events occurring during a given time period) X 10n}}{\text{population at risk during the same time period}}$

Prevalence

- In a study conducted in a community of 10,000 people, researchers found that on January 1st, 2023, 150 individuals were diagnosed with a specific infectious disease. Additionally, during the entire year of 2023, a total of 250 new cases of the same disease were identified. Calculate the point prevalence and the period prevalence of the disease in this community.
- Given:
- Total population = 10,000
- Number of individuals diagnosed with the disease on January 1st, 2023 = 150
- Total number of new cases identified during the entire year of 2023 = 250
- Now, let's calculate:
- **Point Prevalence**: Point Prevalence = (Number of cases on January 1st, 2023 / Total Population) × 100
- Point Prevalence = (150 / 10,000) × 100 Point Prevalence = 1.5%
- **Period Prevalence**: Period Prevalence = (Total number of cases during the year 2023 / Total Population) × 100
- Period Prevalence = (250 / 10,000) × 100 Period Prevalence = 2.5%

Examples

- During the first 6 months of national surveillance for malaria, Kwara state received 1,068 case reports which specified sex; 893 cases were in females, 175 in males. We will demonstrate how to calculate the female-to-male ratio for malaria (12).
- 1. Define x and y: x = cases in females y = cases in males
- 2. Identify x and y: x = 893 y = 175 3. Set up the ratio x/y: 893/175 4.
- Reduce the fraction so that either x or y equals 1: 893/175 = 5.1 to 1
- Thus, there were just over 5 female malaria patients for each male malaria patient reported to CDC.

Proportion calculation

- Based on the data in the example above, we will demonstrate how to calculate the proportion of malaria cases that are male.
- 1. Define x and y: x = cases in males y = all cases
- 2. Identify x and y: x = 175 y = 1,068
- 3. Set up the ratio x/y: 175/1,068
- 4. Reduce the fraction so that either x or y equals 1: 175/1,068 = 0.16/1 = 1/6.10
- Thus, about one out of every 6 reported EMS cases were in males.
- In the first example, we calculated the female-to-male ratio. In the second, we calculated the proportion of cases that were male.
- Is the female-to-male ratio a proportion? The female-to-male ratio is not a proportion, since the numerator (females) is not included in the denominator (males), i.e., it is a ratio, but not a proportion.

Incidence

- An incidence rate (sometimes referred to simply as incidence) is a measure of the frequency with which an event, such as a new case of illness, occurs in a population over a period of time. The formula for calculating an incidence rate follows:
- Incidence rate = $\frac{\text{new cases occurring during a given time period}}{\text{population at risk during the same time period}} \times 10n$

Incidence calculation

- Example
- In 1989, 733,151 new cases of gonorrhea were reported among the United States civilian population. The 1989 mid-year U.S. civilian population was estimated to be 246,552,000.
- For these data we will use a value of 105 for 10n . We will calculate the 1989 gonorrhea incidence rate for the U.S. civilian population using these data.
- 1. Define x and y: x = new cases of gonorrhea in U.S. civilians during 1989 y = U.S. civilian population in 1989
- 2. Identify x, y, and 10n : x = 733,151 y = 246,552,000 10n = 105 = 100,000
- 3. Calculate (x/y) × 10n : 246,552,000 733,151 × 105 =
- .002974 × 100,000 = 297.4 per 100,000 or approximately 3 reported cases per 1,000 population in 1989

Prevalence

Prevalence, sometimes referred to as **prevalence rate**, is the proportion of persons in a population who have a particular disease or attribute at a specified point in time or over a specified period of time. The formula for presence of disease is:

$$Prevalence = \frac{all\ new\ and\ pre\text{-}existing\ cases\ during\ a\ given\ time\ period}{population\ during\ the\ same\ time\ period} \times 10^n$$

The formula for prevalence of an attribute is:

$$Prevalence = \frac{persons\ having\ a\ particular\ attribute\ during\ a\ given\ time\ period}{population\ during\ the\ same\ time\ period} \times 10^n$$

The value of 10^n is usually 1 or 100 for common attributes. The value of 10^n may be 1,000, 100,000, or even 1,000,000 for rare traits and for most diseases.

Point vs. period prevalence

- Sometimes, we want to know how much of a particular disease is present in a population at a single point in time. We use point prevalence for that purpose.
- Point prevalence is not an incidence rate, because the numerator includes pre-existing cases; it is a proportion, because the persons in the numerator are also in the denominator.
- The numerator in point prevalence is the number of persons with a particular disease or attribute on a particular date.
- At other times we want to know how much of a particular disease is present in a population over a longer period.
- Then, we use period prevalence. The numerator in period prevalence is the number of persons who had a particular disease or attribute at any time during a particular interval.
- The interval can be a week, month, year, decade, or any other specified time period.

Period prevalence

- In a survey of patients at a sexually transmitted disease clinic in San Francisco, 180 of 300 patients interviewed reported use of a condom at least once during the 2 months before the interview
- (1). The period prevalence of condom use in this population over the last 2 months is calculated as: 1. Identify x and y: x = condom users = 180 y = total = 300
- 2. Calculate (x/y) × 10n : 180/300 × 100 = 60.0%.
- Thus, the prevalence of condom use in the 2 months before the study was 60% in this population of patients.

Prevalence

- Two surveys were done of the same community 12 months apart. Of 5,000 people surveyed the first time, 25 had antibodies to histoplasmosis.
- Twelve months later, 35 had antibodies, including the original 25. We will calculate the prevalence at the second survey, and compare the prevalence with the 1-year incidence.
- 1. Prevalence at the second survey: x = antibody positive at second survey = 35 y = population = 5,000 x/y × 10n = 35/5,000 × 1,000 = 7 per 1,000
- 2. Incidence during the 12-month period:
- x = number of new positives during the 12-month period =
- 35 − 25 = 10
- y = population at risk = 5,000 − 25 = 4,975
- x/y × 10n = 10/4,975 × 1,000 = 2 per 1,000

Mean

- Mean is the most commonly used measure of central tendency such as arithmetic mean, weighted mean, geometric mean (GM) and harmonic mean (HM).

$$\text{Mean} \qquad \bar{X} = \frac{\Sigma X}{n}$$

$$\text{Mean} \qquad \bar{X} = \frac{\Sigma f x}{n}$$

Median

- The median is the middle value of the ordered data.
- The most important step in finding the median is to first order the data from smallest to largest.
- Steps to finding the median for a set of data:
- Arrange the data in increasing order, i.e. smallest to largest.
- Find the location of the median in the ordered data by n+12, where n is the sample size.
- The value that represents the location found in Step 2 is the median.

Using the formula:

$$\text{Median} = l + \left(\frac{\frac{N}{2} - C}{f}\right) \times h$$

Mode

- **Step 1:** Find the modal class, that is class interval with the maximum frequency.
- **Step 2:** Find the size of the modal class. (upper limit – lower limit.)
- **Step 3:** Calculate the mode using the mode formula:

$$\text{Mode} = L + \left(\frac{f_1 - f_o}{2f_1 - f_o - f_2} \right) h$$

Range

- Range: The range of a set of data is the difference between its largest (maximum) value and its smallest (minimum) value.
- In the epidemiologic community, the range is usually reported as "from (the minimum) to (the maximum)," that is, as two numbers rather than one.
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Standard deviation

- The standard deviation is the measure of spread used most commonly with the arithmetic mean.
- **Step 1.** Calculate the arithmetic mean.
- **Step 2.** Subtract the mean from each observation. Square the difference.
- **Step 3.** Sum the squared differences.
- **Step 4.** Divide the sum of the squared differences by $n - 1$.
- **Step 5.** Take the square root of the value obtained in Step 4. The result is the **standard deviation**.

Standard error of mean

- The standard error of the mean refers to variability we might expect in the arithmetic means of repeated samples taken from the same population.

- *Method for calculating the standard error of the mean*
- **Step 1.** Calculate the standard deviation.
- **Step 2.** Divide the standard deviation by the square root of the number of observations (n).

Herd immunity

- Herd immunity, also known as community immunity, refers to the indirect protection from infectious diseases that occurs when a large proportion of a population becomes immune to the disease, either through vaccination or previous infection.
- When a sufficient proportion of the population is immune, the spread of the infectious agent is significantly reduced because there are fewer susceptible individuals for the pathogen to infect.
- This indirectly protects even those who are not immune, such as individuals who cannot be vaccinated due to medical reasons.
- The threshold for achieving herd immunity depends on the contagiousness of the disease, typically quantified by the basic reproduction number (R0). For highly contagious diseases, such as measles, a higher proportion of the population needs to be immune to achieve herd immunity.
- Herd immunity can be disrupted by factors such as waning immunity over time, vaccine hesitancy, and the introduction of new susceptible individuals into the population (e.g., through births or immigration).

Latency of Infections

- The latency period of an infection refers to the time interval between exposure to the infectious agent and the onset of symptoms or signs of the disease.
- Some infectious diseases have a short latency period, with symptoms appearing shortly after exposure. In contrast, other diseases have a long latency period, with symptoms developing weeks, months, or even years after exposure.
- Latency periods can vary depending on factors such as the type of pathogen, the route of transmission, the dose of the infectious agent, and the host's immune response.
- During the latency period, individuals may be infectious to others even if they do not show symptoms themselves. This poses challenges for disease control and prevention, as asymptomatic or pre-symptomatic individuals can unknowingly spread the infection to others.
- Understanding the latency period of infections is essential for implementing effective control measures, such as quarantine, isolation, contact tracing, and vaccination, to interrupt transmission and prevent outbreaks.

Natural History of diseases

- Natural history of disease refers to the progression of a disease process in an individual over time, in the absence of treatment. For example, untreated infection with HIV causes a spectrum of clinical problems beginning at the time of seroconversion (primary HIV) and terminating with AIDS and usually death.
- The process begins with the appropriate exposure to or accumulation of factors sufficient for the disease process to begin in a susceptible host. For an infectious disease, the exposure is a microorganism.

Spectrum of Disease

- After the disease process has been triggered, pathological changes then occur without the individual being aware of them. This stage of subclinical disease, extending from the time of exposure to onset of disease symptoms, is usually called the **incubation period** for infectious diseases, and the **latency period** for chronic diseases.
- During this stage, disease is said to be asymptomatic (no symptoms) or inapparent. This period may be as brief as seconds for hypersensitivity and toxic reactions to as long as decades for certain chronic diseases. Even for a single disease, the characteristic incubation period has a range.
- The onset of symptoms marks the transition from subclinical to clinical disease. Most diagnoses are made during the stage of clinical disease
- . In others, the disease process may result in illness that ranges from mild to severe or fatal. This range is called the **spectrum of disease**.

Spectrum of Disease contn'd

- For an infectious agent, **infectivity** refers to the proportion of exposed persons who become infected.
- **Pathogenicity** refers to the proportion of infected individuals who develop clinically apparent disease.
- **Virulence** refers to the proportion of clinically apparent cases that are severe or fatal.
- Unfortunately, persons with inapparent or undiagnosed infections may nonetheless be able to transmit infection to others. Such persons who are infectious but have subclinical disease are called **carriers**

Disease Links

- 1. Pathogen: this is the organism that initiate the infection or disease, it could be bacteria, virus, fungi, protozoa etc. Factors such as the virulence (severity of disease), transmissibility (ability to spread from person to person), incubation period, and genetic variability of the pathogen influence its potential to cause outbreaks and spread within populations.
- 2. Reservoir: these are sites in which viable organisms remain active and from whichinfection of individuals might occur. It could be a sitr or a natural environment for the pathogen. It could be animate(carriers) or inaminate (fomites). A carrier could be active, convalescent, healthy or incubatory. The infection could be acute or chronic.
- 3. Transmission: the main routes are air-borne, contact, vehicle and vector borne.
- 4. Host susceptibility:this is the susceptibility of the host to a pathogen which depends on both the pathogenicity of the organisms and the non-specific and specific defense mechanism of the host, genetics, age, underlying health conditions, and immune status
- 5. Pathogen exit from the host: involves the release of the pathogen from the host , it must be successful. Hence, the cycle of disease will be interrupted because their won't be transfer to another host. It can be active or passive.

Disease patterns

- Disease patterns refer to the ways in which diseases are distributed and occur within populations over time
- **Seasonal**: Some diseases exhibit seasonal patterns, with fluctuations in incidence occurring at specific times of the year due to weather conditions, environmental changes, and human behavior.
- **Cyclical**: Certain diseases exhibit cyclical patterns of occurrence, with periodic fluctuations in incidence over time. For example, diseases transmitted by vectors such as mosquitoes (e.g., malaria, dengue fever) may show cyclical patterns related to changes in vector populations, climate variability, and human activities.
- **Emerging and Re-emerging**: Emerging infectious diseases are those that have recently appeared in a population or geographic area or that are increasing in incidence or geographic range. Re-emerging infectious diseases are those that were previously under control but have resurged in recent years.
- **Cluster**: A disease cluster refers to an aggregation of cases of a particular disease within a specific geographic area and time period that is greater than what would be expected by chance.

Zoonoses

- Zoonotic infections, also known as zoonoses, are diseases that can be transmitted from animals to humans.
- These infections can occur through various routes, including direct contact with infected animals, consumption of contaminated food or water, inhalation of aerosols containing infectious agents, and bites from infected arthropods (such as mosquitoes, ticks, and fleas).
- Zoonotic infections are caused by a wide range of pathogens, including bacteria, viruses, parasites, fungi, and prions. Here are some common types of zoonotic infections:

Bacterial Zoonoses

- Examples include:
  - Anthrax: Caused by the bacterium Bacillus anthracis, which can infect humans through contact with contaminated animal products or soil.
  - Brucellosis: Caused by various species of Brucella bacteria, which can be transmitted to humans through contact with infected animals or consumption of unpasteurized dairy products.
  - Leptospirosis: Caused by bacteria of the genus Leptospira, which are transmitted to humans through contact with urine from infected animals or contaminated water.

Viral Zoonoses

- Examples include:
  - Rabies: Caused by the rabies virus, which is transmitted to humans through the bite of an infected animal, typically dogs or wildlife such as bats, raccoons, and foxes.
  - Ebola virus disease: Caused by Ebola virus, which is transmitted to humans through direct contact with infected animals, such as fruit bats, monkeys, and apes, or through contact with bodily fluids of infected individuals.
  - Zika virus disease: Caused by Zika virus, which is primarily transmitted to humans through the bite of infected Aedes mosquitoes but can also be transmitted through sexual contact and from mother to fetus during pregnancy.

Parasitic Zoonoses

- Examples include:
  - Toxoplasmosis: Caused by the parasite Toxoplasma gondii, which can be transmitted to humans through ingestion of contaminated food or water, handling of infected cat feces, or transplacental transmission from mother to fetus.
  - Malaria: Caused by Plasmodium parasites, which are transmitted to humans through the bite of infected Anopheles mosquitoes.
  - Lyme disease: Caused by the bacterium Borrelia burgdorferi, which is transmitted to humans through the bite of infected ticks, primarily black-legged ticks (Ixodes scapularis) in North America.

Fungal Zoonoses

- Examples include:
  - Ringworm: Caused by various species of dermatophyte fungi, which can be transmitted to humans through contact with infected animals or contaminated environments.
  - Cryptococcosis: Caused by the fungus Cryptococcus neoformans, which can be transmitted to humans through inhalation of fungal spores shed by infected birds, particularly pigeons.

Prion Diseases

- Example include:
  - Variant Creutzfeldt-Jakob disease (vCJD): Caused by abnormal prion proteins, which are believed to be transmitted to humans through consumption of meat products contaminated with prions from cattle infected with bovine spongiform encephalopathy (BSE or "mad cow disease").

Preventing zoonotic infections

- Preventing zoonotic infections requires a comprehensive approach that addresses the various pathways through which these diseases are transmitted from animals to humans. Here are several key strategies for preventing zoonotic infections:
- **Surveillance and Monitoring**
- **Public Health Education**
- **Food Safety Measures**
- **Vector Control**
- **Animal Health Management**
- **One Health Approach**
- **Antimicrobial Stewardship**
- **Regulatory Measures**
- **Research and Innovation**

Transmission of zoonoses

- Zoonotic infections can occur through various routes.
- **Direct Contact**:
  - Bites and scratches: Pathogens can be introduced into the human body through wounds caused by bites or scratches from infected animals. Examples include rabies virus transmitted through animal bites and *Pasteurella* bacteria transmitted through cat scratches.
  - Skin-to-skin contact: Skin-to-skin contact with infected animals or their bodily fluids can transmit zoonotic pathogens. For example, contact with lesions or secretions from animals infected with ectoparasites such as scabies mites or ticks can lead to transmission of zoonotic diseases.
  - Inhalation of aerosols: Inhalation of respiratory droplets or aerosols containing infectious agents shed by infected animals can result in respiratory infections in humans. Examples include zoonotic influenza viruses transmitted from birds or pigs to humans.

Indirect Contact

- **Indirect Contact**: Zoonotic infections can also be transmitted indirectly through contact with contaminated environments, objects, or food:
  - Fomite transmission: Examples include *Salmonella* bacteria transmitted through contaminated food or kitchen utensils.
  - Environmental contamination: For example, *Cryptosporidium* parasites transmitted through contaminated water sources or Giardia parasites transmitted through contaminated food.
  - Foodborne transmission: by consumption of contaminated food products of animal origin, such as meat, dairy, eggs, and seafood. Improper handling, storage, or cooking of food can increase the risk of foodborne zoonotic infections. Examples include *Salmonella* and *Campylobacter* bacteria transmitted through undercooked poultry and *E. coli* bacteria transmitted through contaminated beef or produce.

Vector-Borne Transmission:

- **Vector-Borne Transmission**:
  - Mosquito-borne diseases: Mosquitoes can transmit zoonotic pathogens such as West Nile virus, dengue virus, Zika virus, and malaria parasites from infected animals to humans during blood feeding.
  - Tick-borne diseases: Ticks can transmit zoonotic pathogens such as Borrelia bacteria (causing Lyme disease), and tick-borne encephalitis virus from infected animals to humans during feeding.
  - Flea-borne diseases: Fleas can transmit zoonotic pathogens such as *Yersinia pestis* (causing plague) from infected rodents to humans during blood feeding.

Vertical Transmission

- **Vertical Transmission**: Some zoonotic infections can be transmitted from mother to offspring during pregnancy, childbirth, or breastfeeding.
- This can result in congenital infections in newborns or infants.
- Examples include toxoplasmosis caused by *Toxoplasma gondii* and cytomegalovirus (CMV) infection transmitted from pregnant women to their unborn babies.

Antigenic Drift

- Antigenic drift refers to gradual changes in the antigenic properties of a pathogen over time.
- This occurs through the accumulation of mutations in the genes encoding surface proteins, such as hemagglutinin (HA) and neuraminidase (NA) in influenza viruses.
- Influenza viruses undergo antigenic drift due to the error-prone nature of their RNA polymerase enzymes, which can introduce mutations during viral replication.
- These mutations can lead to changes in the amino acid sequence of surface proteins, particularly in regions targeted by host immune responses, such as antigenic epitopes.
- Antigenic drift is a continuous process that results in the generation of new variants or strains of the virus.
- These antigenic variants may evade pre-existing immunity in the population, leading to seasonal epidemics and necessitating regular updates to influenza vaccines to match circulating strains.

Antigenic Shift

- Antigenic shift refers to the abrupt emergence of novel antigenic variants or strains of a pathogen through the reassortment of genetic material between different viral strains.
- This can occur when two or more distinct strains of the virus infect the same host cell and exchange genetic segments.
- If a host is co-infected with different influenza A virus strains, reassortment can occur, resulting in the emergence of a novel reassortant virus with antigenic properties distinct from those of the parental strains.
- Antigenic shift has the potential to lead to the emergence of pandemic influenza strains.
- Historic examples include the 1957 Asian flu pandemic, the 1968 Hong Kong flu pandemic, and the 2009 H1N1 influenza pandemic.

Biological products

- A biological product is a substance derived from a living organism and used for the prevention or treatment of disease.
- Biologicals are usually too complex for chemical synthesis by a laboratory.
- These products include antitoxins, bacterial and viral vaccines, blood products and hormone extracts.

Vaccines

- **Live Attenuated Vaccines**:
  - Live attenuated vaccines contain weakened forms of the disease-causing organism (virus or bacterium) that are still capable of replicating within the body but cause only mild or no symptoms of disease. These vaccines mimic natural infection, stimulating a strong and long-lasting immune response.
  - Examples include the measles, mumps, and rubella (MMR) vaccine, oral polio vaccine (OPV), varicella (chickenpox) vaccine, and yellow fever vaccine.
- **Inactivated Vaccines**:
  - Inactivated vaccines contain killed or inactivated forms of the disease-causing organism. These vaccines cannot replicate within the body and typically require booster doses to maintain immunity.
- Examples include the injectable polio vaccine (IPV), hepatitis A vaccine, influenza vaccine (inactivated influenza vaccine or IIV), and rabies vaccine.

Vaccines

- **Subunit, Recombinant, and Conjugate Vaccines**:
  - Subunit vaccines contain purified antigens or protein subunits derived from the pathogen. Recombinant vaccines are produced by genetic engineering techniques to express specific antigens or proteins of the pathogen. Conjugate vaccines combine antigens from the pathogen with a carrier protein to enhance the immune response, particularly in young children.
  - Examples include the hepatitis B vaccine (recombinant subunit), human papillomavirus (HPV) vaccine (recombinant subunit), pneumococcal conjugate vaccine (conjugate), and Haemophilus influenzae type b (Hib) vaccine (conjugate).
- **Toxoid Vaccines**:
  - Toxoid vaccines contain inactivated toxins produced by certain bacteria. These vaccines stimulate the production of neutralizing antibodies against the toxin, preventing the development of disease caused by toxin-producing bacteria.
  - Examples include the diphtheria toxoid-containing vaccines (DTaP, Tdap), tetanus toxoid-containing vaccines (DTaP, Tdap), and pertussis (whooping cough) vaccine (acellular pertussis component).

Vaccines

- **Viral Vector Vaccines**:
  - Viral vector vaccines use a modified virus, such as an adenovirus or a modified vaccinia virus, as a vector to deliver genetic material encoding antigens from the target pathogen. These vaccines elicit both cellular and humoral immune responses.
  - Examples include the COVID-19 vaccines developed using adenovirus vectors (e.g., AstraZeneca/Oxford vaccine, Johnson & Johnson's Janssen vaccine).
- **Nucleic Acid Vaccines**:
  - Nucleic acid vaccines, such as mRNA vaccines, deliver genetic material encoding antigens directly into cells to induce antigen production within the body. These vaccines have demonstrated efficacy and rapid development potential.
  - Examples include the mRNA COVID-19 vaccines developed by Pfizer-BioNTech and Moderna.

Monoclonal Antibodies

- Monoclonal antibodies are used to treat a variety of diseases caused by cancer cells, infectious agents or toxic inflammatory substances.
- These antibodies are produced in laboratories in a cell culture to create multiple identical forms of the same cell.
- This results in very pure antibodies that act against specific antigens.
- Research is targeted at producing antibodies targeted at prion-related diseases that cause severe damage to brain cells in humans and animals, such as transmissible spongiform encephalopathy, Creutzfeldt-Jakob disease and chronic wasting disease.

Blood Fractions and Serums

- Products prepared from donated blood include red cells, white cells, platelets, and plasma which is fractionated to albumin, immune serum globulins (including specialized products such as tetanus, Rh and rabies immunoglobulins), and coagulation factor concentrates for the treatment of hemophilias A and B.

- Hemosol BioPharma Inc, a Toronto biotechnology company, develops blood-protein based products, which avoids the potential risks associated with blood.