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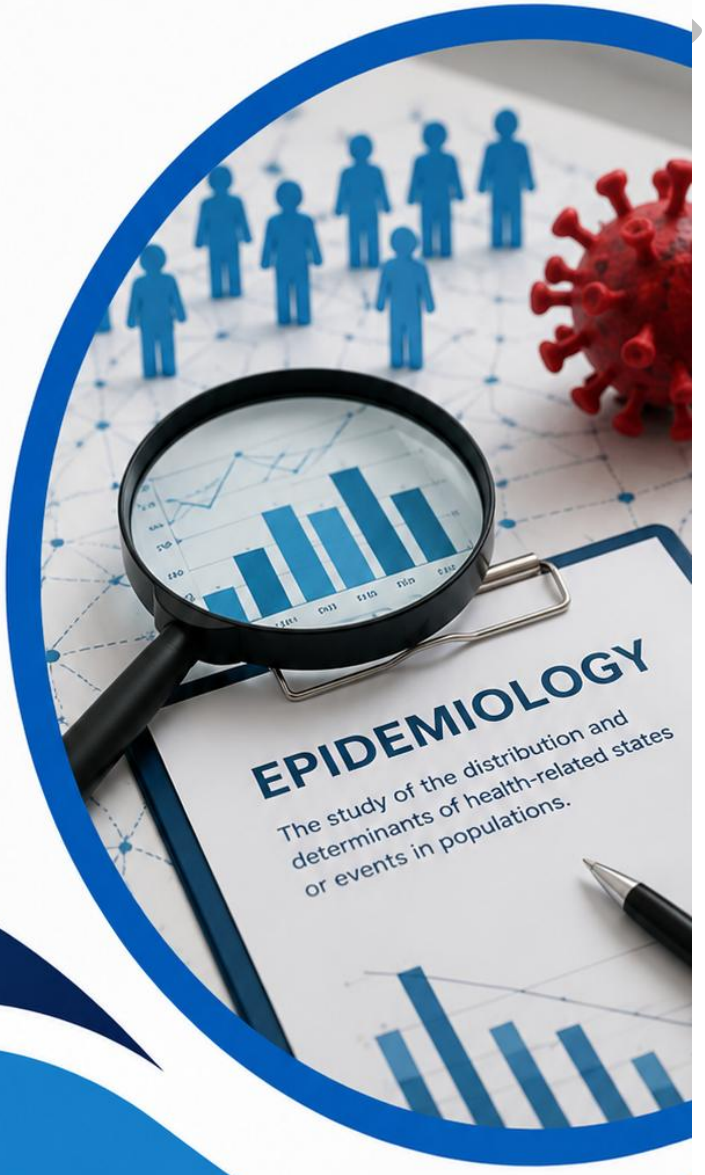
COM 308

INTRODUCTION TO GENERAL EPIDEMIOLOGY



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Course code: COM 308

Course title: Introduction to General Epidemiology

Course credit load: 2 Units

Series 1: Foundations and Uses of Epidemiology

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Introduction

Epidemiology is the basic science of public health. Before any health programme can be designed, before any outbreak can be controlled, and before any treatment can be evaluated, someone must first establish how much disease exists, who it affects, and why. Epidemiology provides the systematic methods for answering these questions, transforming scattered clinical observations into the population-level evidence that drives public health action.

The aim of this Series is to introduce you to the definition, scope, and historical development of epidemiology, to distinguish its major types, to establish the basic concepts that underlie all epidemiological reasoning, and to survey the practical uses of epidemiology in public health and clinical practice.

We shall commence by defining epidemiology and tracing its historical development. Next, we will distinguish the major types of epidemiology: descriptive, analytical, and experimental. Moving on, we will examine the basic concepts of disease occurrence, the epidemiological triad, and the natural history of disease. Finally, we will close by surveying the practical uses of epidemiology in surveillance, health planning, and clinical practice.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 1.1** define epidemiology and trace its historical development,
- **SLO 1.2** distinguish between descriptive, analytical, and experimental epidemiology,
- **SLO 1.3** explain the concept of disease occurrence and the population at risk,
- **SLO 1.4** describe the epidemiological triad and explain the multifactorial nature of disease causation,
- **SLO 1.5** describe the natural history of disease and the levels of prevention, and
- **SLO 1.6** list and explain the major uses of epidemiology in public health and clinical practice.

1.1 Definition and Scope of Epidemiology

1.1.1 Definition and core concepts of epidemiology

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 the control of health problems. This widely cited WHO definition contains three core elements: **distribution** (the frequency and pattern of disease, examined by person, place, and time), **determinants** (the factors, exposures, and causes that influence disease occurrence), and **application** (the use of epidemiological findings to prevent and control disease). Epidemiology is therefore not merely descriptive science; it is an applied discipline oriented toward action.

A defining feature of epidemiology is its **population orientation**. Whereas clinical medicine focuses on the individual patient, epidemiology focuses on groups of people, asking not "why did this person become ill?" but "why did this population experience this much illness, and why did it occur in this pattern?" This population perspective is what allows epidemiology to identify risk factors, evaluate interventions, and inform policies that the individual clinical encounter cannot reveal on its own.

Fill in the blank: Epidemiology is the study of the distribution and _____ of health-related states or events in specified populations, and the application of this study to the control of health problems.

1.1.2 Historical development of epidemiology

Epidemiology has ancient roots. **Hippocrates** (circa 400 BC) is often credited as the first epidemiologist for his work "On Airs, Waters, and Places," which proposed that disease occurrence was related to environmental factors rather than purely supernatural causes. The modern discipline, however, traces its decisive origin to **John Snow**, whose investigation of the 1854 London cholera outbreak demonstrated that cases clustered around the Broad Street water pump, leading him to remove the pump handle and halt the outbreak before the causative organism (Vibrio cholerae) had even been identified. Snow work exemplifies the

epidemiological method: using patterns of disease distribution to identify causes and act on them, even before complete biological understanding is available.

The twentieth century saw epidemiology mature into a quantitative science. **Doll and Hill** landmark cohort studies in the 1950s established the causal link between smoking and lung cancer. The **Framingham Heart Study**, begun in 1948, established the modern concept of cardiovascular risk factors. In the latter twentieth and early twenty-first centuries, epidemiology expanded beyond infectious and chronic disease to address injury, mental health, environmental exposures, and global health security, reflected in Nigeria own epidemiological capacity development through the Nigeria Field Epidemiology and Laboratory Training Programme (NFELTP), established to build a skilled workforce for outbreak detection and response.

Fill in the blank: _____ investigation of the 1854 London cholera outbreak, which traced cases to the Broad Street water pump, is considered the foundational study establishing the modern epidemiological method.

1.1.3 The epidemiological approach to disease

Epidemiology approaches disease through a systematic sequence of questions: who is affected (person), where does disease occur (place), when does it occur (time), and why does it occur (determinants)? This sequence moves from **descriptive** questions (what is the pattern?) to **analytical** questions (what explains the pattern?) to **action** (what can be done about it?). This systematic approach distinguishes epidemiological reasoning from anecdotal or intuitive impressions of disease patterns, which are often biased by which cases happen to be most memorable or visible to an individual observer.

Central to the epidemiological approach is the comparison of disease frequency across groups. A single case, or even many cases, tells us little in isolation; epidemiological insight emerges from comparing rates between exposed and unexposed groups, between different time periods, or between different places. This comparative logic underlies every epidemiological method introduced later in this course, from simple descriptive comparisons to the formal analytical study designs of Series 3.

Fill in the blank: Central to the epidemiological approach is the _____ of disease frequency across groups, such as exposed versus unexposed populations, which allows patterns to be distinguished from chance variation.

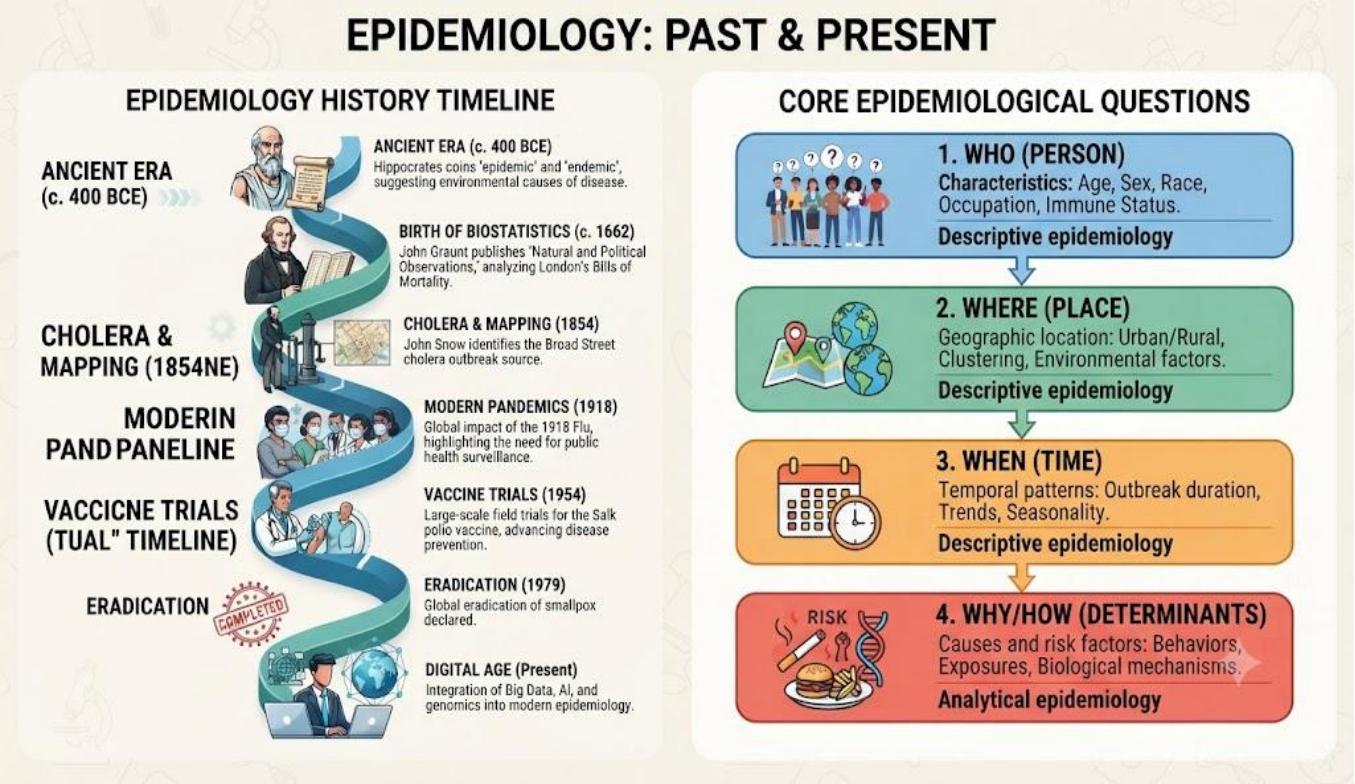

Figure 1.1: The historical development and core questions of epidemiology

Pilot questions 1.1

1. Define epidemiology according to the WHO definition.
2. Why is epidemiology described as having a population orientation?
3. What did John Snow do during the 1854 London cholera outbreak?
4. Name two landmark epidemiological studies of the twentieth century.
5. What is the comparative logic that underlies epidemiological reasoning?

1.2 Types of Epidemiology

1.2.1 Descriptive epidemiology

Descriptive epidemiology is concerned with characterising the distribution of disease in a population by person, place, and time, without testing specific hypotheses about cause. It answers the questions: who is affected, where does disease occur, and when does it occur? Descriptive studies include case reports, case series, cross-sectional surveys, and the analysis of routinely collected health statistics. Descriptive epidemiology is typically the first step in any epidemiological investigation, providing the foundational picture of disease patterns from which hypotheses about causation can later be generated.

Descriptive epidemiology is sometimes underestimated as merely preliminary, but it serves essential functions in its own right: monitoring disease trends over time, identifying populations at greatest need, allocating health resources, and generating the hypotheses that analytical studies subsequently test. In Nigeria, the Integrated Disease Surveillance and Response (IDSR) system is fundamentally a descriptive epidemiology tool, generating the routine data on disease occurrence by person, place, and time that triggers further investigation when unusual patterns emerge. Series 2 of this course is dedicated entirely to descriptive epidemiology.

Fill in the blank: Descriptive epidemiology characterises the distribution of disease by person, place, and time without testing specific hypotheses about _____ , and is typically the first step in any epidemiological investigation.

1.2.2 Analytical epidemiology

Analytical epidemiology goes beyond description to test specific hypotheses about the causes of disease, typically by comparing disease frequency between groups with different exposures. Analytical studies are classified as **observational** (the investigator observes existing exposures and outcomes without intervening) or **experimental** (the investigator actively assigns exposure, as in a clinical trial). Major observational analytical designs include the **cohort study** (following exposed and unexposed groups forward in time to compare disease incidence) and the **case-control study** (comparing the exposure history of diseased cases against non-diseased controls).

Analytical epidemiology produces the evidence that establishes or refutes causal hypotheses generated by descriptive studies. For example, descriptive data showing high lung cancer rates among smokers generates the hypothesis that smoking causes lung cancer; analytical cohort and case-control studies (such as those conducted by Doll and Hill) then test this hypothesis directly by comparing disease incidence between smokers and non-smokers, producing the quantitative measures of association (relative risk, odds ratio) needed to evaluate the strength of the relationship. Series 3 of this course examines analytical methods in detail.

Fill in the blank: Analytical epidemiology tests specific hypotheses about disease causation by comparing disease frequency between groups with different _____ , using study designs such as the cohort study and the case-control study.

1.2.3 Experimental and other epidemiology types

Experimental epidemiology (also called intervention epidemiology) involves the investigator actively assigning an exposure or intervention to study participants and observing the outcome, providing the strongest evidence for causal relationships because random allocation minimises confounding. The **randomised controlled trial (RCT)** is the gold standard experimental design, used to evaluate the efficacy of treatments, vaccines, and preventive interventions. **Field trials** apply experimental methods to healthy populations to test preventive interventions (such as vaccine trials), while **community trials** randomise whole communities rather than individuals, appropriate when the intervention operates at the community level (such as a water chlorination programme).

Beyond this three-part classification, epidemiology is also organised by application domain: **clinical epidemiology** applies epidemiological methods to clinical decision-making (diagnostic test evaluation, prognosis, treatment effectiveness); **environmental epidemiology** studies the health effects of environmental exposures; **molecular epidemiology** integrates biological markers into epidemiological investigation; and **field epidemiology** applies epidemiological methods in real-time outbreak investigation, the practical foundation of the NFELTP training programme in Nigeria. These domains are not mutually exclusive; a single epidemiologist may apply descriptive, analytical, and experimental methods within any of these application areas.

Fill in the blank: The randomised controlled trial is the gold standard _____ epidemiological design because random allocation of the intervention minimises confounding and provides the strongest evidence for causal relationships.

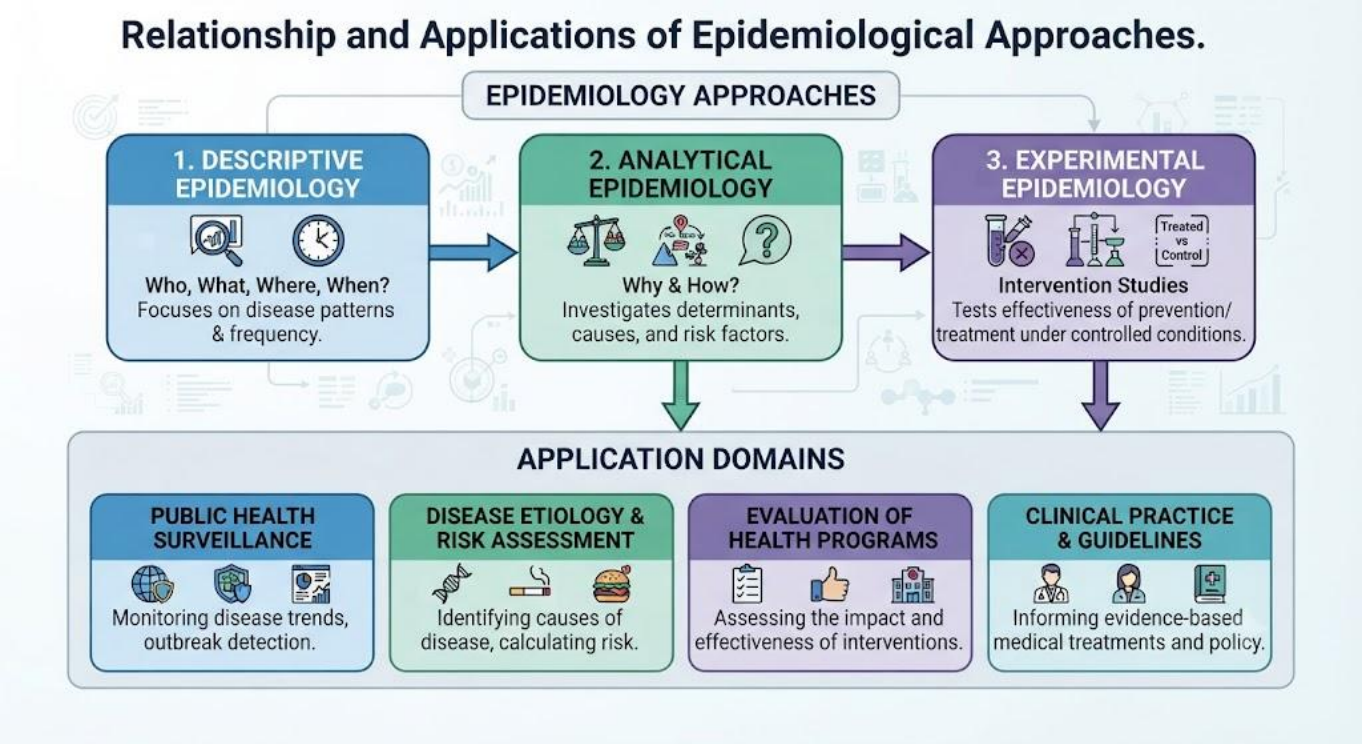

Figure 1.2: The three types of epidemiology and their relationships

Pilot questions 1.2

1. What questions does descriptive epidemiology answer?
2. Distinguish between observational and experimental analytical studies.
3. Name the two major observational analytical study designs.
4. Why is the randomised controlled trial considered the gold standard design?
5. Distinguish between a field trial and a community trial.

1.3 Basic Concepts Underlying Epidemiology

1.3.1 The concepts of disease occurrence and population at risk

Disease occurrence in epidemiology is quantified using two fundamental concepts introduced more fully in later Series: **incidence** (the occurrence of new cases over a defined period) and **prevalence** (the existence of cases at a point or period in time). Underlying both measures is the concept of the **population at risk**: the group of people who are susceptible to developing the disease being studied and who therefore form the correct denominator for any rate calculation. A population at risk excludes individuals who cannot develop the disease (for example, men cannot be included in the population at risk for cervical cancer, and individuals who have already had a disease that confers permanent immunity, such as measles, may be excluded from the population at risk for that disease).

Correctly defining the population at risk is a frequent source of error in epidemiological calculations. An incidence rate calculated using the total population, when the disease in question can only occur in a subset of that population, will systematically underestimate the true risk. For example, calculating the incidence of prostate cancer using the entire population (including women) rather than the male population alone produces a rate that understates the true risk to men. Precise denominator definition is therefore not a technical nicety but a requirement for valid epidemiological measurement.

Fill in the blank: The population at _____ is the group of people who are susceptible to developing the disease being studied and who form the correct denominator for any epidemiological rate calculation.

1.3.2 The epidemiological triad and causation

The **epidemiological triad** (or epidemiological triangle) is a classical model of disease causation comprising three interacting elements: the **agent** (the causative factor, which may be biological, such as a pathogen, chemical, physical, or nutritional), the **host** (the susceptible human or animal, whose characteristics including age, sex, genetic makeup, immune status, and behaviour influence susceptibility), and the **environment** (the external conditions, including physical,

biological, and social factors, that influence exposure and the interaction between agent and host). Disease occurs when these three elements interact in a way that overcomes the host resistance.

Modern epidemiology recognises that most disease, particularly chronic non-communicable disease, results from **multifactorial causation** rather than a single agent. The concept of a **web of causation** depicts disease as the product of multiple interacting causal pathways, each contributing partially to the outcome. Rothman **sufficient-component cause model** formalises this: a **sufficient cause** is a set of minimal conditions that inevitably produces disease, and within that sufficient cause, individual **component causes** (such as smoking, in a sufficient cause for lung cancer that also includes genetic susceptibility and other exposures) are neither necessary nor sufficient alone. This multicausal framework better reflects the reality of chronic disease epidemiology than the simple triad, which remains most applicable to infectious disease.

Fill in the blank: The epidemiological triad comprises three interacting elements in disease causation: the agent, the host, and the _____, and disease occurs when these elements interact in a way that overcomes host resistance.

1.3.3 The natural history of disease and levels of prevention

The **natural history of disease** describes the progression of a disease process from initial exposure through to resolution, in the absence of intervention. It comprises a **pre-pathogenesis phase** (before disease begins, when the host, agent, and environment interact but pathological changes have not yet started), and a **pathogenesis phase**, which includes a **subclinical (latent) period** (pathological changes have begun but no symptoms are present, sometimes detectable only through screening), the **clinical phase** (symptoms appear, leading to diagnosis), and an **outcome** (recovery, disability, or death). Understanding where a disease sits within this natural history determines the appropriate point and type of intervention.

Leavell and Clark **levels of prevention** framework maps onto the natural history of disease: **primary prevention** acts before disease onset, in the pre-pathogenesis phase, through health promotion (nutrition, education) and specific protection (immunisation, safe water); **secondary prevention** acts during the subclinical phase, through early detection and screening to interrupt

progression before symptoms emerge; and **tertiary prevention** acts during the clinical phase, through treatment to limit disability and rehabilitation to restore function. This framework provides the conceptual basis for the disease control strategies examined in Series 4 and 5 of this course.

Fill in the blank: The natural history of disease comprises a pre-pathogenesis phase and a pathogenesis phase, the latter including a subclinical (latent) period, a clinical phase, and an _____ such as recovery, disability, or death.

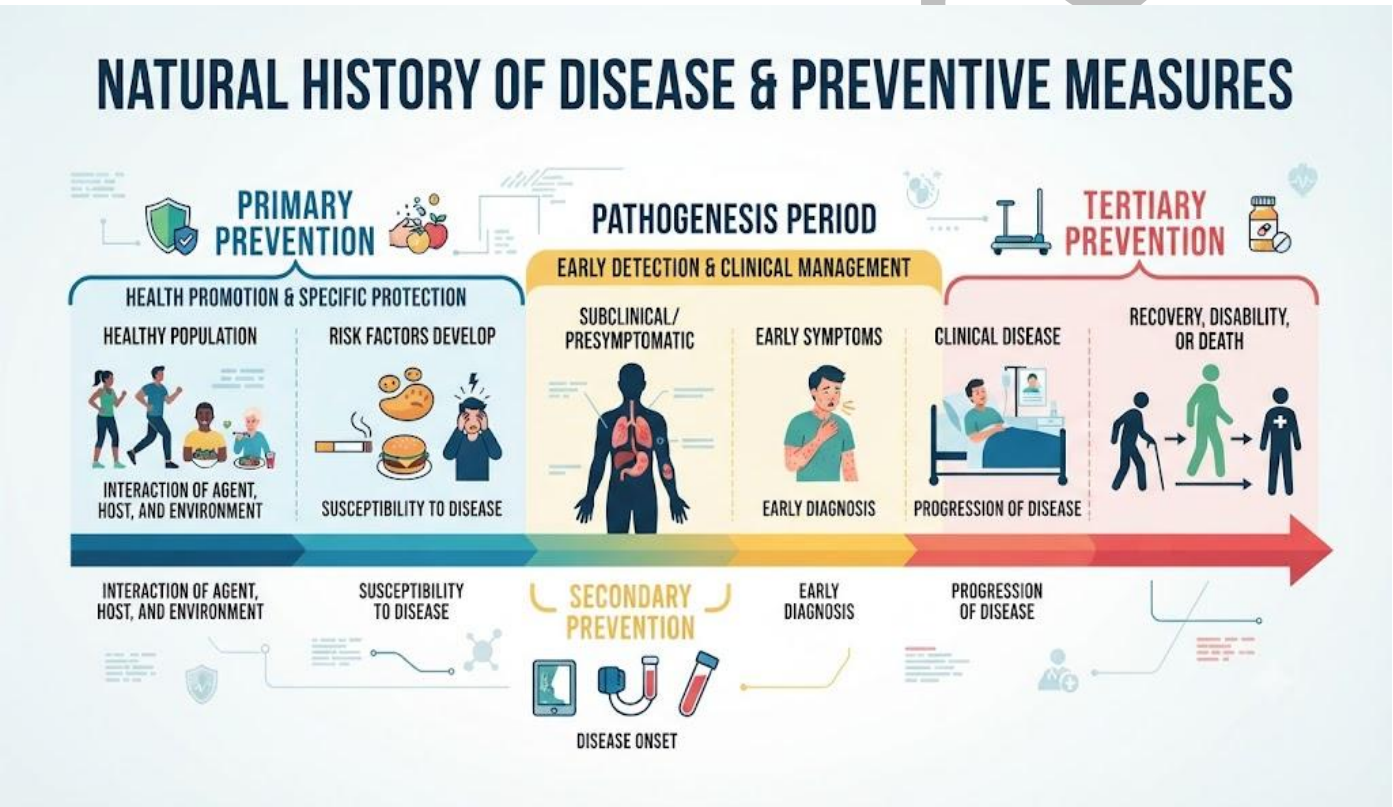

Figure 1.3: The natural history of disease and levels of prevention

Pilot questions 1.3

1. Define the population at risk and give one example of correctly excluding a subgroup.
2. Name the three elements of the epidemiological triad.
3. What is a sufficient cause in Rothman model of causation?
4. Name the four phases of the natural history of disease.

5. Match each level of prevention (primary, secondary, tertiary) to the phase of the natural history of disease at which it intervenes.

1.4 Uses of Epidemiology

1.4.1 Epidemiology in disease surveillance and outbreak investigation

Epidemiology provides the foundational methods for **disease surveillance**: the ongoing, systematic collection, analysis, and interpretation of health data essential to the planning, implementation, and evaluation of public health practice. In Nigeria, the IDSR system applies epidemiological principles to detect unusual disease patterns that may signal an outbreak, triggering further investigation. **Outbreak investigation** applies epidemiological methods in real time to identify the source, mode of transmission, and population at risk during a disease outbreak, generating the evidence needed for immediate control measures, as exemplified by John Snow original cholera investigation and replicated in every modern outbreak response, from Lassa fever to cholera to COVID-19 in Nigeria.

The practical skills of outbreak investigation, including establishing a case definition, conducting descriptive epidemiological analysis, generating and testing hypotheses through analytical methods, and implementing and evaluating control measures, are taught through field epidemiology training programmes such as the NFELTP. This use of epidemiology is examined in depth in Series 4 of this course, which addresses the systematic steps of epidemic investigation.

Fill in the blank: Disease _____ is the ongoing, systematic collection, analysis, and interpretation of health data essential to the planning, implementation, and evaluation of public health practice, exemplified in Nigeria by the IDSR system.

1.4.2 Epidemiology in health planning and policy

Epidemiological data on disease burden, risk factors, and population health needs form the evidence base for **health planning** decisions: determining which diseases to prioritise, where to locate health facilities, how to allocate workforce, and which interventions to fund. The Global Burden of Disease framework, the demographic and vital statistics methods covered in related courses, and the disease frequency measures of epidemiology together generate the data that distinguishes evidence-based health planning from planning based on assumption or political pressure alone.

Epidemiology also informs **health policy** through the evaluation of the population-level effects of policy interventions: did a tobacco taxation policy reduce smoking prevalence and lung cancer incidence? Did a malaria control programme reduce malaria mortality? Epidemiological evaluation provides the evidence that policymakers require to demonstrate accountability for public health investment and to refine policies that are not achieving their intended effect. In Nigeria, the National Strategic Health Development Plan and disease-specific national strategies (malaria, HIV, tuberculosis) are informed by epidemiological surveillance and survey data.

Fill in the blank: Epidemiological data on disease burden, risk factors, and population health needs form the _____ base for health planning decisions, distinguishing it from planning based on assumption or political pressure alone.

1.4.3 Epidemiology in clinical practice and evaluation

At the level of individual clinical practice, **clinical epidemiology** applies population-level methods to improve clinical decision-making. Epidemiological principles underlie the evaluation of **diagnostic tests** (sensitivity, specificity, predictive values, discussed in Series 4), the assessment of **prognosis** (using cohort study methods to determine the likely course of a disease), and the evaluation of **treatment effectiveness** (using randomised controlled trial methods to determine whether a treatment genuinely improves outcomes beyond what would occur without it). Evidence-based medicine, examined in related courses, is fundamentally an application of epidemiological reasoning to the individual clinical encounter.

Epidemiology also underpins **programme and intervention evaluation**: did a new clinical protocol reduce hospital-acquired infection rates? Did a community health worker programme increase antenatal care attendance? These evaluation questions require the same comparative logic that underlies all epidemiological reasoning: comparing outcomes between groups exposed and not exposed to the intervention, accounting for confounding factors, and quantifying the magnitude and statistical significance of any observed effect. Mastery of epidemiological methods is therefore essential not only for public health specialists but for any health professional committed to evidence-based practice.

Fill in the blank: _____ -based medicine, the application of epidemiological reasoning to individual clinical decisions, relies on epidemiological methods to evaluate diagnostic tests, assess prognosis, and determine treatment effectiveness.

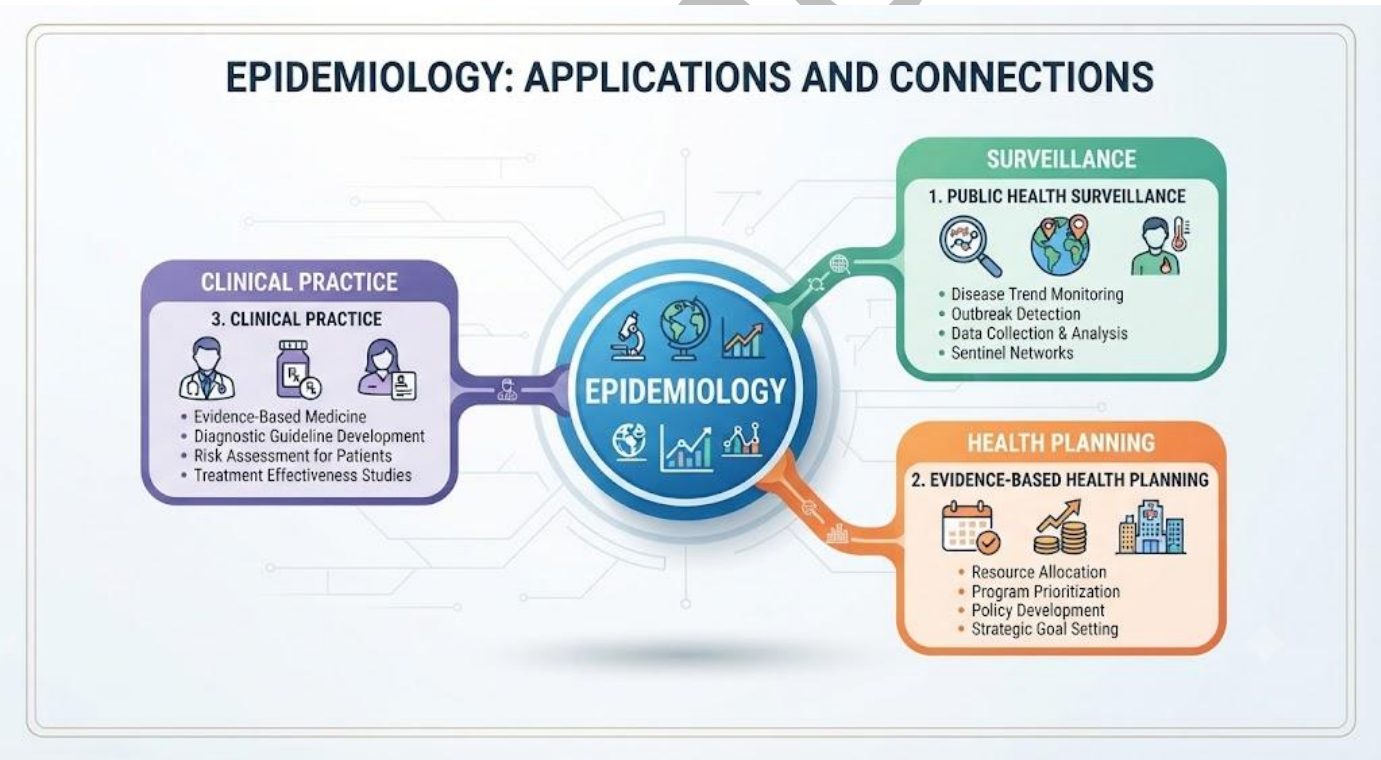

Figure 1.4: The uses of epidemiology across the health system

Pilot questions 1.4

1. What is disease surveillance and give a Nigerian example?
2. How does epidemiology inform health planning decisions?

3. Name three clinical applications of epidemiological methods.
4. What is clinical epidemiology?
5. Give one example of how epidemiology can be used to evaluate a health intervention.

Series Summary

This Series introduced epidemiology as the basic science of public health, defined through its concern with the distribution and determinants of disease and the application of this knowledge to control health problems. The historical development of the discipline was traced from Hippocrates through John Snow foundational cholera investigation to the modern quantitative studies of Doll and Hill and the Framingham Heart Study. The three types of epidemiology, descriptive, analytical, and experimental, were distinguished, establishing the progression from characterising disease patterns to testing causal hypotheses to confirming causation through controlled intervention.

The basic concepts underlying epidemiological reasoning were established: the population at risk as the correct denominator for disease occurrence measures, the epidemiological triad and the multifactorial web of causation as models of disease causation, and the natural history of disease mapped against the three levels of prevention. The Series concluded by surveying the practical uses of epidemiology in disease surveillance, outbreak investigation, health planning, policy evaluation, and clinical practice, establishing epidemiology as a discipline whose value lies in its application across the entire spectrum of health system activity (SLOs 1.1 to 1.6).

Glossary of Terms

- **Analytical epidemiology:** the branch of epidemiology that tests specific hypotheses about disease causation by comparing disease frequency between groups with different exposures.
- **Descriptive epidemiology:** the branch of epidemiology concerned with characterising the distribution of disease by person, place, and time without testing causal hypotheses.
- **Epidemiological triad:** a model of disease causation comprising the interacting elements of agent, host, and environment.
- **Epidemiology:** 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.

- **Experimental epidemiology:** the branch of epidemiology in which the investigator actively assigns exposure or intervention, such as in a randomised controlled trial.
- **Levels of prevention:** the Leavell and Clark framework of primary, secondary, and tertiary prevention, mapped to phases in the natural history of disease.
- **Natural history of disease:** the progression of a disease process from initial exposure through to resolution in the absence of intervention.
- **Population at risk:** the group of people susceptible to developing a given disease, forming the correct denominator for epidemiological rate calculations.
- **Randomised controlled trial:** an experimental study design in which participants are randomly allocated to receive an intervention or not, considered the gold standard for establishing causation.
- **Sufficient cause:** in Rothman causal model, a set of minimal conditions that inevitably produces disease, composed of multiple component causes none of which is necessary or sufficient alone.

Concept Check Questions [Series 1]

Objective questions

1. Epidemiology is the study of the distribution and _____ of health-related states or events in specified populations. (Linked to SLO 1.1)
2. _____ investigation of the 1854 London cholera outbreak is considered the foundational study establishing the modern epidemiological method. (Linked to SLO 1.1)
3. _____ epidemiology characterises the distribution of disease by person, place, and time without testing causal hypotheses. (Linked to SLO 1.2)
4. The three elements of the epidemiological triad are agent, host, and _____. (Linked to SLO 1.4)
5. _____ prevention acts during the subclinical phase of disease through early detection and screening. (Linked to SLO 1.5)
6. Disease _____ is the ongoing, systematic collection, analysis, and interpretation of health data essential to public health practice. (Linked to SLO 1.6)

Short-answer questions

7. Distinguish between descriptive, analytical, and experimental epidemiology, giving one example study design of each. (Linked to SLO 1.2)
8. Explain the population at risk and why its correct definition matters for valid epidemiological measurement. (Linked to SLO 1.3)
9. Describe the natural history of disease and explain how the three levels of prevention map onto it. (Linked to SLO 1.5)

Long-answer questions

10. Discuss the historical development of epidemiology and explain how it shapes the modern epidemiological approach to disease. (Linked to SLOs 1.1–1.2)
11. Evaluate the epidemiological triad and the multifactorial model of causation, explaining their relevance to infectious and chronic disease respectively. (Linked to SLOs 1.4–1.5)
12. Discuss the uses of epidemiology across surveillance, health planning, and clinical practice, illustrating with examples relevant to Nigeria. (Linked to SLO 1.6)

Answers to Concept Check Questions [Series 1]

Objective questions

1. Determinants.
2. John Snow.
3. Descriptive.
4. Environment.
5. Secondary.
6. Surveillance.

Short-answer questions

7. Descriptive epidemiology characterises disease distribution by person, place, and time without testing hypotheses; example: cross-sectional survey. Analytical epidemiology tests causal hypotheses by comparing exposed and unexposed groups; example: cohort study or case-control study. Experimental epidemiology actively assigns exposure to test causation; example: randomised controlled trial.
8. The population at risk is the group of people susceptible to developing the disease being studied, forming the correct denominator for rate calculations. Correct definition matters because using an incorrect denominator (e.g. the total population instead of only those who can develop the disease) systematically distorts the calculated rate, understating or overstating the true risk.
9. Natural history: pre-pathogenesis phase, subclinical (latent) phase, clinical phase, outcome. Primary prevention acts in the pre-pathogenesis phase (health promotion, specific protection). Secondary prevention acts in the subclinical phase (screening, early detection). Tertiary prevention acts in the clinical phase (treatment to limit disability, rehabilitation to restore function).

Long-answer questions

10. **Basic response:** Hippocrates linked disease to environmental factors. John Snow 1854 cholera investigation traced cases to the Broad Street pump, demonstrating disease pattern analysis could identify and control a cause before the causative organism was known. Doll and Hill established smoking-lung cancer causation through cohort studies. The Framingham Heart Study established

the cardiovascular risk factor concept. Nigeria NFELTP builds modern field epidemiology capacity.

Value-added response: These historical milestones established the enduring logic of epidemiology: that comparing disease frequency across groups (exposed versus unexposed, before versus after intervention) reveals causal patterns even without complete biological understanding. Snow acted on pattern evidence alone; modern epidemiology has added quantitative rigor (relative risk, confidence intervals) to this same comparative logic, but the underlying method, established 170 years ago, remains the foundation of every outbreak investigation conducted in Nigeria today.

11. **Basic response:** The epidemiological triad (agent, host, environment) models disease as the product of three interacting elements; it is most applicable to infectious disease, where a specific biological agent is necessary. The multifactorial web of causation and Rothman sufficient-component cause model recognise that chronic disease typically results from multiple interacting causes, none necessary or sufficient alone (e.g. lung cancer from smoking, genetic susceptibility, and other exposures combined).

Value-added response: The shift from the triad to multifactorial models reflects the epidemiological transition: as infectious disease mortality declined and chronic disease became dominant, a single-agent model proved inadequate to explain disease patterns. In Nigeria, where infectious and chronic diseases now coexist as a double burden, both models remain relevant simultaneously: the triad for malaria and Lassa fever investigation, the multifactorial model for the rising burden of hypertension, diabetes, and cardiovascular disease.

12. **Basic response:** Surveillance: IDSR system in Nigeria applies epidemiological methods to detect unusual disease patterns and trigger outbreak investigation. Health planning: epidemiological burden of disease data informs facility location, workforce allocation, and national strategic health plans (malaria, HIV, TB strategies). Clinical practice: clinical epidemiology evaluates diagnostic tests, assesses prognosis, and determines treatment effectiveness through evidence-based medicine; programme evaluation applies the same comparative logic to assess whether interventions achieve their intended effect.

Value-added response: These three uses are interconnected rather than separate: surveillance data identifies a rising disease burden, health planning translates this into resource allocation decisions, and clinical epidemiology evaluates whether the resulting interventions actually work. A Nigerian

health system that severs these connections, for instance failing to evaluate whether resources allocated based on surveillance data actually improve outcomes, loses the feedback loop that makes epidemiology valuable as an applied rather than purely academic discipline.

Answers to Pilot Questions [Series 1]

Part 1.1

1. 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 the control of health problems.
2. Epidemiology focuses on groups of people rather than individual patients, asking why a population experienced a given pattern of illness rather than why a single individual became ill, which allows it to identify risk factors and inform interventions at the population level.
3. John Snow traced cases of cholera to the Broad Street water pump and removed the pump handle, halting the outbreak before the causative organism (Vibrio cholerae) had been identified.
4. Any two of: Doll and Hill smoking and lung cancer cohort studies; the Framingham Heart Study establishing cardiovascular risk factors.
5. Comparing disease frequency between exposed and unexposed groups, between different time periods, or between different places, rather than relying on isolated case observations.

Part 1.2

1. Who is affected (person), where does disease occur (place), and when does it occur (time).
2. Observational studies involve the investigator observing existing exposures and outcomes without intervening; experimental studies involve the investigator actively assigning the exposure or intervention.
3. The cohort study and the case-control study.
4. Random allocation of the intervention minimises confounding, ensuring that any observed difference in outcome between groups can be attributed to the intervention rather than to pre-existing differences between groups.

5. A field trial applies experimental methods to healthy populations to test preventive interventions, such as a vaccine trial. A community trial randomises whole communities rather than individuals, appropriate when the intervention operates at the community level, such as a water chlorination programme.

Part 1.3

1. The population at risk is the group of people susceptible to developing the disease being studied. Example: men are excluded from the population at risk for cervical cancer, since they cannot develop the disease.
2. Agent, host, and environment.
3. A sufficient cause is a set of minimal conditions that inevitably produces disease; it is composed of multiple component causes, none of which is necessary or sufficient to cause disease alone.
4. Pre-pathogenesis, subclinical (latent), clinical, and outcome.
5. Primary prevention intervenes in the pre-pathogenesis phase. Secondary prevention intervenes in the subclinical phase. Tertiary prevention intervenes in the clinical phase.

Part 1.4

1. Disease surveillance is the ongoing, systematic collection, analysis, and interpretation of health data essential to public health practice. Nigerian example: the Integrated Disease Surveillance and Response (IDSR) system.
2. Epidemiological data on disease burden, risk factors, and population health needs form the evidence base for deciding which diseases to prioritise, where to locate health facilities, and how to allocate workforce and funding.
3. Any three of: evaluation of diagnostic tests (sensitivity and specificity), assessment of prognosis, evaluation of treatment effectiveness.
4. Clinical epidemiology is the application of population-level epidemiological methods to improve individual clinical decision-making, including the evaluation of diagnostic tests, prognosis, and treatment effectiveness.

5. Comparing outcomes between a group receiving an intervention (such as a community health worker programme) and a group not receiving it, to determine whether the intervention produced a measurable improvement, such as increased antenatal care attendance.

References and Attributions [Series 1]

Textual references

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Figures, Plates, Tables, and Boxes

- Figure 1.1: The historical development and core questions of epidemiology Attribution: AI generated using prompt "Generate a timeline of epidemiology history alongside a diagram of the four core epidemiological questions (person, place, time, determinants) in sequence." Suggested OER search string: "history of epidemiology John Snow cholera timeline epidemiological questions who where when why OER"
- Figure 1.2: The three types of epidemiology and their relationships Attribution: AI generated using prompt "Generate a flow diagram showing the relationship between descriptive, analytical, and experimental epidemiology with application domains listed." Suggested OER search string: "descriptive analytical experimental epidemiology cohort case-control randomised controlled trial OER"
- Figure 1.3: The natural history of disease and levels of prevention Attribution: AI generated using prompt "Generate a horizontal timeline showing the natural history of disease with primary, secondary, and tertiary prevention mapped to the corresponding phase." Suggested OER search string: "natural history of disease levels of prevention primary secondary tertiary Leavell Clark timeline OER"

- Figure 1.4: The uses of epidemiology across the health system Attribution: AI generated using prompt "Generate a hub-and-spoke diagram showing epidemiology at the centre with three application branches: surveillance, health planning, and clinical practice." Suggested OER search string: "uses of epidemiology surveillance health planning clinical practice evidence-based medicine OER"

Course code: COM 308

Course title: Introduction to General Epidemiology

Course credit load: 2 Units

Series 2: Descriptive Epidemiology — Person, Place, and Time

- **Part 2.1: Descriptive Epidemiology by Person**
  - Sub Part 2.1.1: Age and sex as person characteristics
  - Sub Part 2.1.2: Socioeconomic, ethnic, and behavioural characteristics
  - Sub Part 2.1.3: Genetic and biological host factors
- **Part 2.2: Descriptive Epidemiology by Place**
  - Sub Part 2.2.1: International and national variation in disease occurrence
  - Sub Part 2.2.2: Urban-rural and local area variation
  - Sub Part 2.2.3: Mapping disease distribution
- **Part 2.3: Descriptive Epidemiology by Time**
  - Sub Part 2.3.1: Secular (long-term) trends
  - Sub Part 2.3.2: Cyclical and seasonal variation
  - Sub Part 2.3.3: Point epidemics and the epidemic curve
- **Part 2.4: Synthesising Descriptive Epidemiology**
  - Sub Part 2.4.1: Integrating person, place, and time data
  - Sub Part 2.4.2: Generating hypotheses from descriptive data
  - Sub Part 2.4.3: Descriptive epidemiology in the Nigerian context

Introduction

Before any cause can be investigated, the pattern of disease must first be described accurately. Descriptive epidemiology answers three deceptively simple questions: who is affected, where does disease occur, and when does it occur? The answers to these questions, examined systematically through the characteristics of person, place, and time, generate the hypotheses that analytical epidemiology subsequently tests, and provide the foundational evidence that surveillance and health planning depend upon.

The aim of this Series is to examine descriptive epidemiology in depth through its three classical dimensions: person, place, and time, and to demonstrate how these dimensions are integrated to generate epidemiological hypotheses, with specific application to the Nigerian disease context.

We shall commence by examining descriptive epidemiology by person, covering age, sex, socioeconomic, and genetic characteristics. Next, we will examine descriptive epidemiology by place, from international comparison to local mapping. Moving on, we will examine descriptive epidemiology by time, covering secular trends, seasonal variation, and epidemic curves. Finally, we will close by synthesising person, place, and time data into hypothesis generation for the Nigerian context.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 2.1** describe how age, sex, and other person characteristics influence disease occurrence,
- **SLO 2.2** explain the role of socioeconomic, behavioural, and genetic factors in descriptive epidemiology,
- **SLO 2.3** describe international, national, and local variation in disease occurrence by place,
- **SLO 2.4** explain the use of disease mapping in descriptive epidemiology,

- **SLO 2.5** distinguish between secular trends, cyclical variation, and point epidemics in the time dimension,
- **SLO 2.6** interpret an epidemic curve, and
- **SLO 2.7** integrate person, place, and time data to generate epidemiological hypotheses relevant to Nigeria.

2.1 Descriptive Epidemiology by Person

2.1.1 Age and sex as person characteristics

Age is the single most powerful person characteristic in descriptive epidemiology: nearly every disease shows a characteristic age pattern, reflecting differences in exposure, physiological susceptibility, immune status, and cumulative risk over the life course. Infectious diseases such as measles and whooping cough cluster in young children due to lack of acquired immunity; chronic diseases such as cardiovascular disease and cancer increase with age due to cumulative exposure and biological ageing; injury mortality peaks in young adult men due to risk-taking behaviour and occupational exposure. Age-specific analysis is therefore the starting point for almost any descriptive epidemiological investigation.

Sex differences in disease occurrence arise from a combination of biological factors (hormonal influences, genetic factors related to the X and Y chromosomes, anatomical differences) and social or behavioural factors (occupational exposure patterns, health-seeking behaviour, risk behaviours such as smoking and alcohol use, which historically differ by sex). In Nigeria, malaria mortality is higher in pregnant women due to pregnancy-related immune changes; cervical cancer affects only women; prostate cancer affects only men; and road traffic injury mortality is substantially higher in men, reflecting both occupational exposure (commercial driving) and risk behaviour patterns.

Fill in the blank: _____ is the single most powerful person characteristic in descriptive epidemiology, with nearly every disease showing a characteristic pattern reflecting differences in exposure, susceptibility, and cumulative risk over the life course.

2.1.2 Socioeconomic, ethnic, and behavioural characteristics

Socioeconomic status (commonly measured by income, education, and occupation) is among the most consistent and powerful determinants of disease occurrence across virtually all conditions. Lower socioeconomic groups generally experience higher rates of infectious disease (due to crowding, poor sanitation, and limited healthcare access), higher rates of many chronic diseases (due to diet, stress, and limited access to preventive care), and higher mortality across nearly all causes. This pattern, often termed the **social gradient** in health, is observed consistently across countries and time periods, including in Nigeria, where poverty is strongly associated with higher rates of malaria, diarrhoeal disease, and maternal mortality.

Ethnicity and **religion** may be associated with disease occurrence through genetic factors (such as sickle cell disease, which has higher prevalence in populations of West African descent), cultural practices (dietary patterns, marriage customs affecting consanguinity rates), and the geographic and socioeconomic patterns that often correlate with ethnic group in a given country. **Behavioural characteristics** including smoking, alcohol use, diet, physical activity, and sexual behaviour are major determinants of non-communicable and some infectious disease risk; descriptive epidemiology examines how these behaviours and their associated disease outcomes are distributed across population subgroups, providing the basis for targeted health promotion interventions.

Fill in the blank: The _____ gradient in health describes the consistent pattern in which lower socioeconomic groups experience higher rates of disease and mortality across virtually all conditions, observed across countries and time periods.

2.1.3 Genetic and biological host factors

Genetic factors influence individual susceptibility to disease through several mechanisms: **single-gene disorders** (such as sickle cell disease, caused by a specific genetic mutation with high prevalence in Nigeria, particularly among populations with historical exposure to malaria, where carrying one copy of the sickle cell trait confers partial protection against severe malaria); **polygenic susceptibility** (multiple genes each contributing small increments of risk for conditions such as diabetes, hypertension, and many cancers); and **gene-environment**

interaction (genetic susceptibility that only manifests as disease in the presence of a specific environmental exposure, such as glucose-6-phosphate dehydrogenase deficiency, which causes haemolysis specifically when triggered by certain drugs or foods).

Other biological host factors relevant to descriptive epidemiology include **immune status** (prior infection or vaccination conferring immunity, or conditions such as HIV infection or malnutrition impairing immune function and increasing susceptibility to a wide range of infections), **nutritional status** (malnutrition increasing susceptibility to infectious disease and impairing child development, a major determinant of disease patterns in Nigerian children), and **physiological state** (pregnancy, for example, altering susceptibility to malaria, influenza, and other infections). These biological host factors interact with the social and behavioural characteristics discussed previously to produce the observed pattern of disease in any population.

Fill in the blank: _____ -environment interaction describes genetic susceptibility that only manifests as disease in the presence of a specific environmental exposure, as in G6PD deficiency, which causes haemolysis only when triggered by certain drugs or foods.

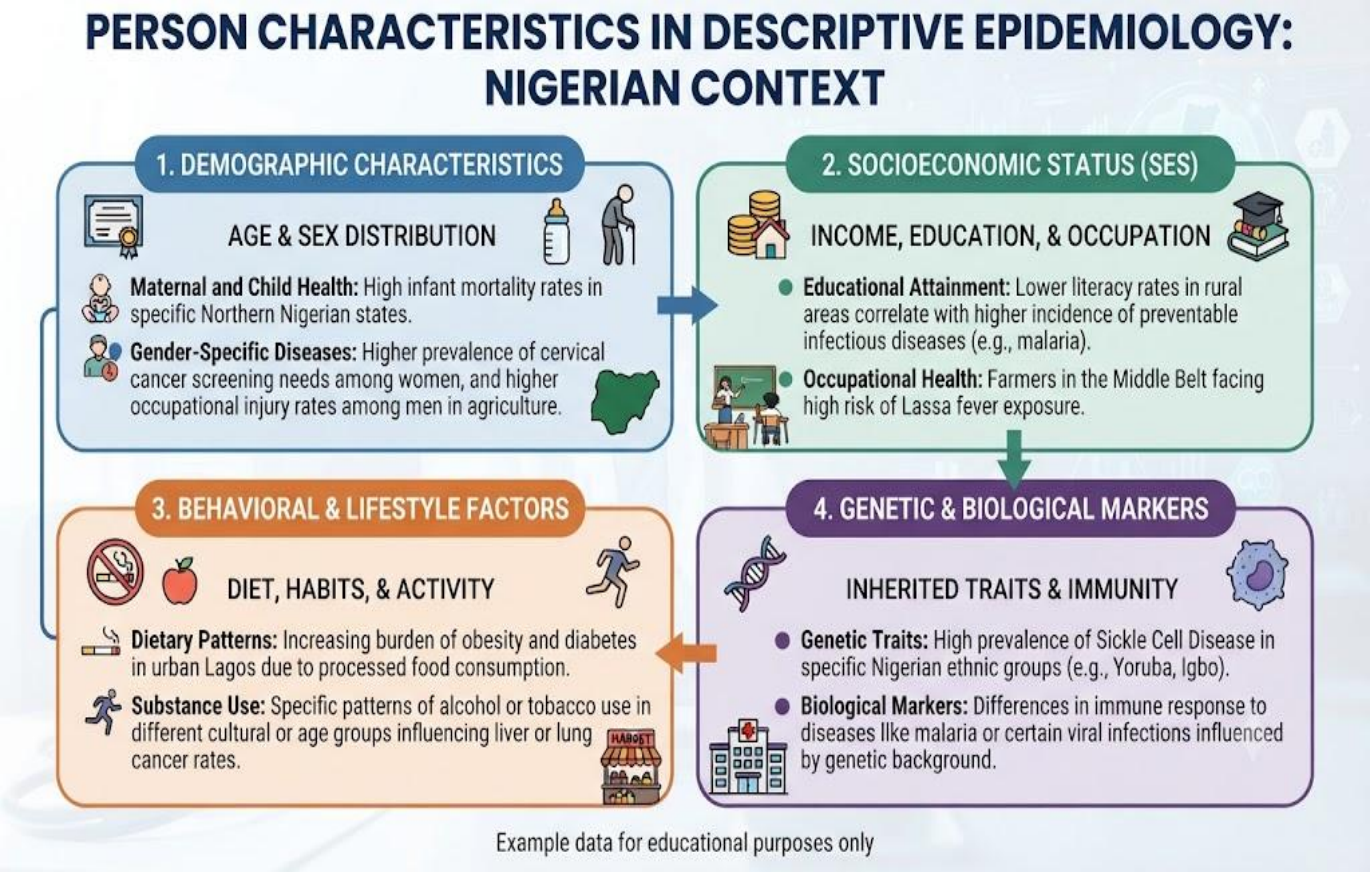


Figure 2.1: Person characteristics in descriptive epidemiology

Pilot questions 2.1

1. Why is age considered the single most powerful person characteristic in descriptive epidemiology?
2. Give two examples of diseases or outcomes that differ by sex in Nigeria.
3. What is the social gradient in health?
4. Give an example of a gene-environment interaction relevant to Nigeria.
5. Name three biological host factors that influence disease susceptibility.

2.2 Descriptive Epidemiology by Place

2.2.1 International and national variation in disease occurrence

Disease occurrence varies dramatically across countries, reflecting differences in climate, economic development, healthcare infrastructure, cultural practices, and historical exposure patterns. **International comparison** reveals, for example, that malaria burden is concentrated in tropical and sub-tropical regions, with sub-Saharan Africa, including Nigeria, accounting for the majority of global malaria cases and deaths; that non-communicable disease burden is proportionally greater in high-income countries with older populations, though rising rapidly in middle-income countries undergoing the epidemiological transition; and that maternal mortality remains concentrated in low-income countries with weak health systems.

Within a country, **national or sub-national variation** reflects similar underlying determinants operating at a smaller geographic scale. In Nigeria, malaria transmission intensity varies by ecological zone, with higher transmission in the humid south and lower, more seasonal transmission in the drier north. Maternal mortality is substantially higher in the north-east and north-west geopolitical zones than in the south-west, reflecting differences in health service access, female education, and early marriage practices. Lassa fever is concentrated in specific states of the south and Middle Belt where the rodent reservoir species is endemic. Mapping these variations is essential for targeting resources to the areas of greatest need.

Fill in the blank: Sub-Saharan Africa, including Nigeria, accounts for the majority of global _____ cases and deaths, reflecting the concentration of this disease in tropical and sub-tropical regions with favourable vector ecology.

2.2.2 Urban-rural and local area variation

Within any country, disease patterns differ systematically between **urban and rural** areas. Urban areas typically have better access to formal healthcare and improved water and sanitation infrastructure (where these have kept pace with population growth), but face risks from overcrowding, air pollution, and the chronic disease burden associated with urban lifestyle and dietary transition. Rural areas typically have more limited healthcare access and higher rates of

certain infectious and vector-borne diseases, but may have lower exposure to some urban-associated chronic disease risk factors. In Nigeria, this pattern is complicated by the substantial gap between formal urban infrastructure and the reality of large informal urban settlements, which combine urban population density with rural-level service deficits.

At an even finer geographic scale, **local area variation** (sometimes called **small-area analysis**) examines disease clustering at the level of neighbourhoods, wards, or specific institutions. This level of analysis can reveal localised environmental hazards (a cluster of cases near a contaminated water source or industrial facility), localised outbreaks, or service access gaps within an otherwise well-served urban area. Local area analysis often requires geographic information system (GIS) tools to map case locations against environmental, infrastructural, and demographic data layers, enabling the precise targeting of investigation and intervention.

Fill in the blank: Local area variation, sometimes called small-area analysis, examines disease clustering at the level of neighbourhoods or wards, often requiring geographic information system (_____) tools to map case locations against environmental and demographic data.

2.2.3 Mapping disease distribution

Disease mapping is one of the oldest and most powerful tools of descriptive epidemiology, exemplified by John Snow original spot map of cholera cases around the Broad Street pump. Modern disease mapping uses **spot maps** (marking the location of each individual case, useful for visually identifying clusters), **choropleth maps** (shading geographic areas, such as states or local government areas, according to disease rate, useful for comparing burden across administrative units), and **GIS-based spatial analysis** (overlaying disease data with environmental, infrastructural, and demographic layers to identify spatial associations and generate hypotheses about causation).

In Nigeria, disease mapping has practical application in malaria control (mapping transmission intensity to target indoor residual spraying and bed net distribution), in polio eradication (mapping case locations to identify chains of transmission and target vaccination campaigns), and in outbreak investigation (mapping cases during a cholera or Lassa fever outbreak to identify the source and guide the geographic scope of the response). **Spatial clustering statistics** (formal

statistical tests for whether observed case clustering exceeds what would be expected by chance) provide a more rigorous complement to visual map inspection, helping to distinguish genuine disease clusters from random variation.

Fill in the blank: _____ maps shade geographic areas, such as states or local government areas, according to disease rate, allowing comparison of disease burden across administrative units.

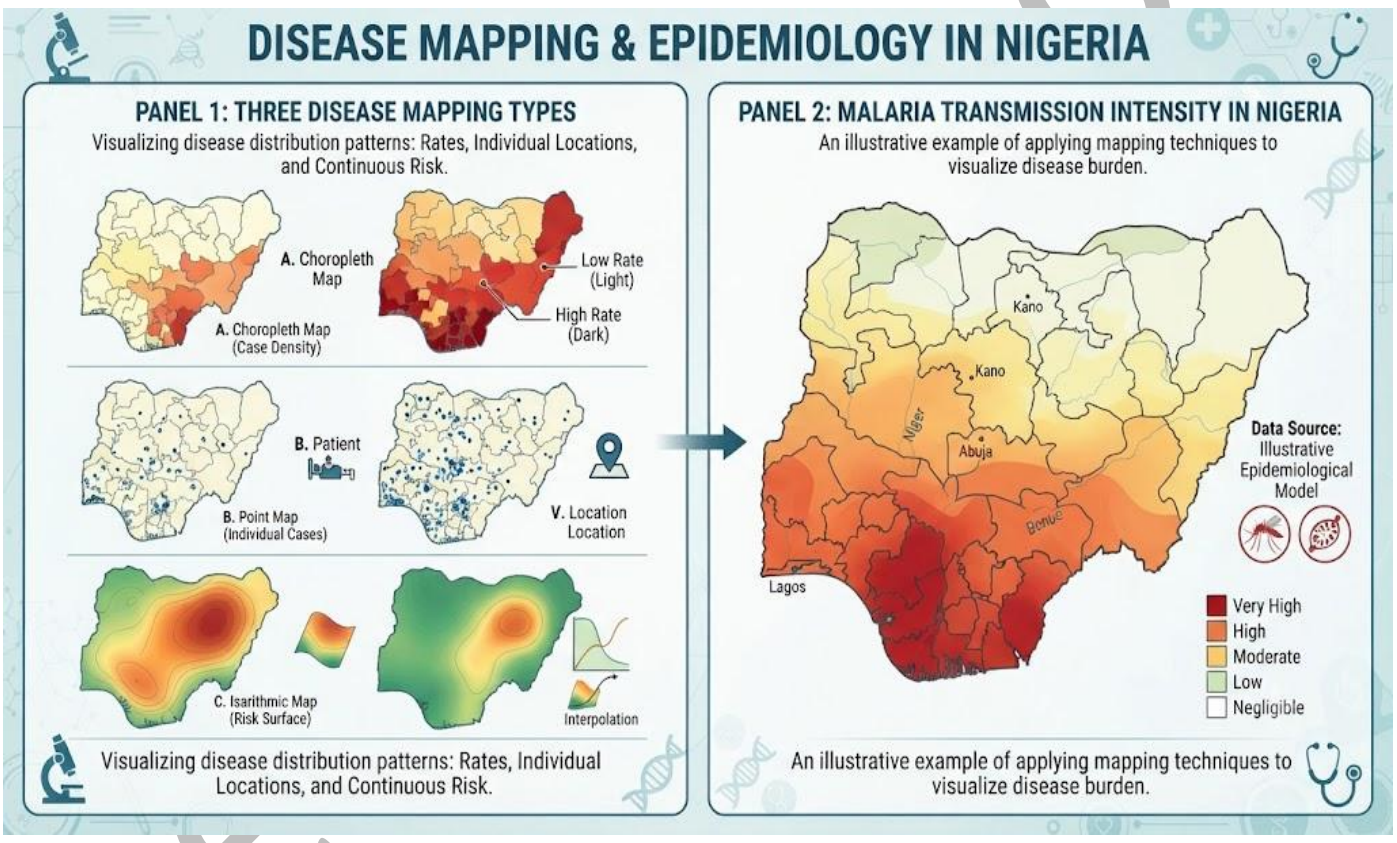


Figure 2.2: Disease mapping methods and geographic variation in Nigeria

Pilot questions 2.2

1. Why does malaria burden concentrate in sub-Saharan Africa?
2. Name two diseases or health outcomes that vary geographically within Nigeria and explain why.
3. Distinguish between urban and rural disease patterns, noting the complication specific to Nigeria.

4. Distinguish between a spot map and a choropleth map.
5. Give one practical application of disease mapping in Nigeria.

2.3 Descriptive Epidemiology by Time

2.3.1 Secular (long-term) trends

Secular trends (also called long-term trends) describe gradual changes in disease occurrence over years or decades, reflecting underlying changes in risk factor prevalence, healthcare access, population structure, or diagnostic practice. Examples of secular trends include the gradual decline in global smallpox incidence leading to eradication in 1980, the rising global trend in obesity and type 2 diabetes prevalence over recent decades, and the declining trend in child mortality across most countries, including Nigeria, since the 1990s, attributable to improved immunisation coverage, nutrition, and access to basic health services.

Identifying genuine secular trends requires distinguishing real changes in disease occurrence from **artefactual changes** arising from improved diagnostic technology (detecting cases that previously went undiagnosed), changes in disease definition or classification, changes in reporting completeness, or changes in the population denominator. In Nigeria, apparent increases in reported cancer or diabetes incidence over recent decades may partly reflect genuine increases in disease occurrence (driven by ageing population and lifestyle change) and partly reflect improved diagnostic capacity and disease registration, requiring careful interpretation before concluding that the underlying disease burden has truly changed.

Fill in the blank: _____ trends describe gradual changes in disease occurrence over years or decades, which must be distinguished from artefactual changes arising from improved diagnosis, changed disease definitions, or improved reporting completeness.

2.3.2 Cyclical and seasonal variation

Cyclical variation refers to disease patterns that recur at regular intervals longer than one year, often reflecting the build-up and depletion of susceptible individuals in a population (as immunity from a previous epidemic wanes or as a birth cohort of susceptible children accumulates) combined with the periodic introduction of an infectious agent; measles outbreaks in under-vaccinated populations have historically shown multi-year cyclical patterns for this reason. **Seasonal variation** refers to regular within-year fluctuation in disease occurrence, typically driven by climate-related changes in vector abundance, pathogen survival, indoor crowding, or behaviour.

In Nigeria, seasonal variation is a defining feature of several major diseases: **malaria** transmission peaks during and shortly after the rainy season, when mosquito breeding sites are abundant; **cholera** outbreaks cluster during the rainy season, linked to flooding and water contamination; **meningitis** epidemics in the northern meningitis belt cluster during the dry, dusty harmattan season (roughly November to April), when the dry air and dust are believed to damage the nasopharyngeal mucosa, facilitating bacterial invasion; and **measles** transmission often peaks during the dry season when indoor crowding increases. Understanding seasonal patterns allows health authorities to time preventive interventions, such as seasonal malaria chemoprevention and meningitis vaccination campaigns, for maximum impact.

Fill in the blank: _____ epidemics in the northern meningitis belt of Nigeria cluster during the dry, dusty harmattan season, when the dry air and dust are believed to facilitate bacterial invasion of the nasopharyngeal mucosa.

2.3.3 Point epidemics and the epidemic curve

A **point epidemic (point-source epidemic)** occurs when a group of people are exposed to a common source of infection or contamination over a brief period, producing a sharp rise and fall in case numbers clustered around the average incubation period of the disease after the point of exposure. A **propagated (continuous) epidemic** occurs through person-to-person transmission, producing a series of successive waves, each separated by approximately one incubation period, with case numbers building more gradually and persisting longer than a point epidemic.

The **epidemic curve** (epi curve) is a histogram of case counts plotted against time of onset, and is one of the most powerful tools in outbreak investigation: its shape provides immediate visual evidence about the likely mode of transmission. A sharp, narrow peak with a single dominant rise and fall suggests a point-source exposure (such as a contaminated food item at a single event). A series of declining peaks, each spaced roughly one incubation period apart, suggests person-to-person (propagated) transmission. A prolonged, irregular pattern may suggest a continuous common-source exposure (such as an ongoing contaminated water supply) rather than a single point exposure. Constructing and interpreting the epidemic curve is a foundational skill in outbreak investigation, examined further in Series 4.

Fill in the blank: A point _____ occurs when a group of people are exposed to a common source of infection over a brief period, producing a sharp rise and fall in case numbers on the epidemic curve clustered around the average incubation period.

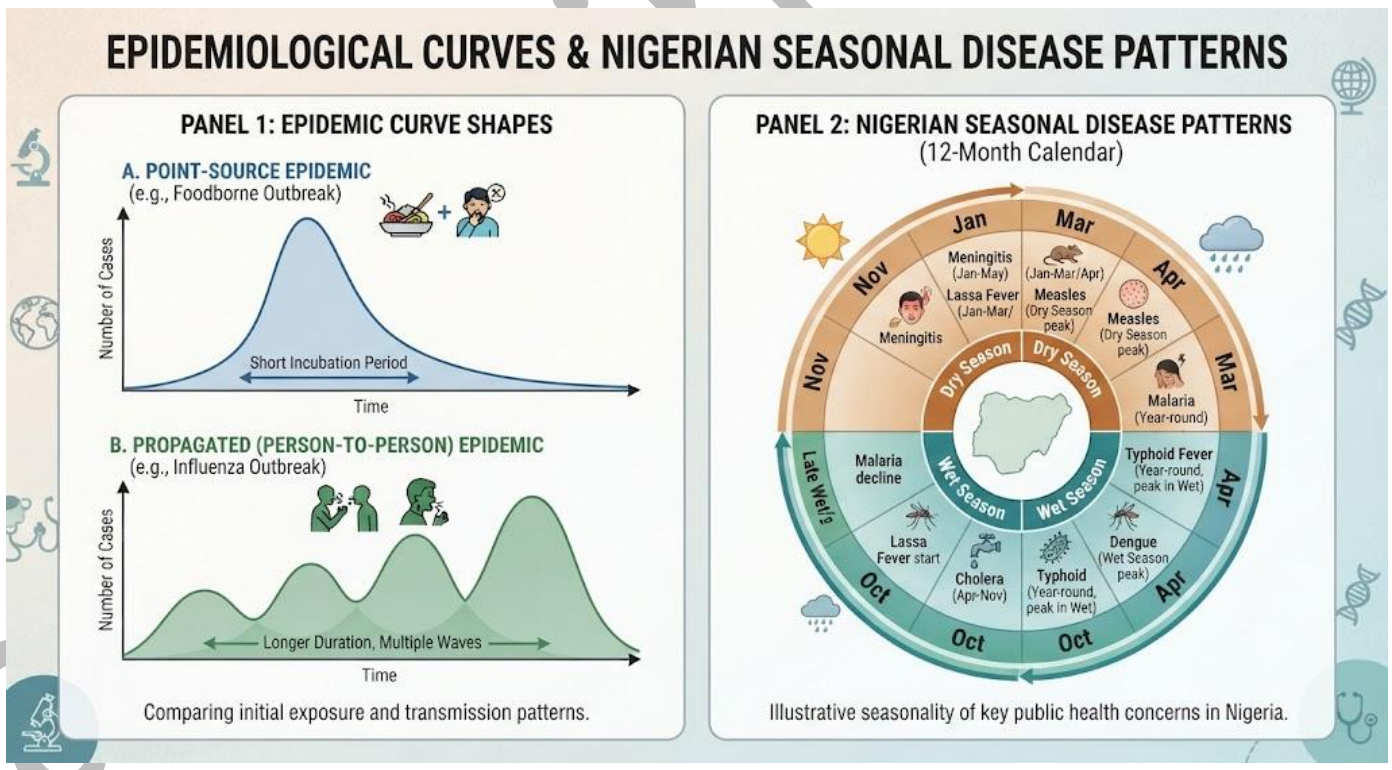


Figure 2.3: Patterns of disease occurrence over time

Pilot questions 2.3

1. Define a secular trend and give one example.
2. Distinguish between cyclical and seasonal variation.
3. When does meningitis epidemic activity peak in northern Nigeria and why?
4. Distinguish between a point-source epidemic and a propagated epidemic.
5. What does the shape of an epidemic curve reveal about the likely mode of transmission?

2.4 Synthesising Descriptive Epidemiology

2.4.1 Integrating person, place, and time data

The full analytical power of descriptive epidemiology emerges not from examining person, place, and time in isolation, but from integrating all three dimensions simultaneously. A complete descriptive picture of a disease answers: which population subgroups are affected (person), in which geographic areas (place), and during which time periods (time)? Cross-tabulating these dimensions, for example examining age-specific malaria incidence by state and by month, reveals patterns that none of the three dimensions alone would expose: perhaps the disease burden is concentrated in young children in specific northern states during the post-rainy season, a pattern with direct implications for the timing and targeting of seasonal malaria chemoprevention.

This integrated approach is the standard methodology of routine disease surveillance systems including Nigeria IDSR, which collects person, place, and time data on notifiable conditions continuously, enabling the detection of unusual deviations from expected patterns in any of the three dimensions, which may signal an emerging outbreak. A sudden increase in cases in a single local government area (place), a cluster of cases in a specific age group not typically affected (person), or a rise in cases outside the expected seasonal pattern (time) all serve as triggers for further investigation.

Fill in the blank: The full analytical power of descriptive epidemiology emerges from _____ person, place, and time data simultaneously, revealing patterns that none of the three dimensions alone would expose.

2.4.2 Generating hypotheses from descriptive data

Descriptive epidemiology generates causal hypotheses through the identification of patterns that suggest, without proving, a possible explanation. If a disease occurs disproportionately in a specific age group, this suggests hypotheses related to age-specific exposure, susceptibility, or behaviour. If a disease clusters in a specific geographic area, this suggests hypotheses related to environmental exposure, vector ecology, or healthcare access in that area. If a disease shows a seasonal pattern, this suggests hypotheses related to climate-dependent vector activity, behaviour, or pathogen survival. These hypotheses, generated from descriptive patterns, are then formally tested using the analytical study designs covered in Series 3.

A critical principle in hypothesis generation from descriptive data is that **association observed in descriptive data does not establish causation**. Descriptive patterns may reflect genuine causal relationships, but they may equally reflect confounding (a third factor associated with both the apparent exposure and the outcome), reverse causation, or chance. The descriptive epidemiologist role is to generate plausible, testable hypotheses; the analytical epidemiologist role, examined in the next Series, is to test those hypotheses rigorously and quantify the strength of any genuine causal association.

Fill in the blank: A critical principle in hypothesis generation from descriptive data is that association observed in such data does not establish _____ , since patterns may reflect confounding, reverse causation, or chance rather than a genuine causal relationship.

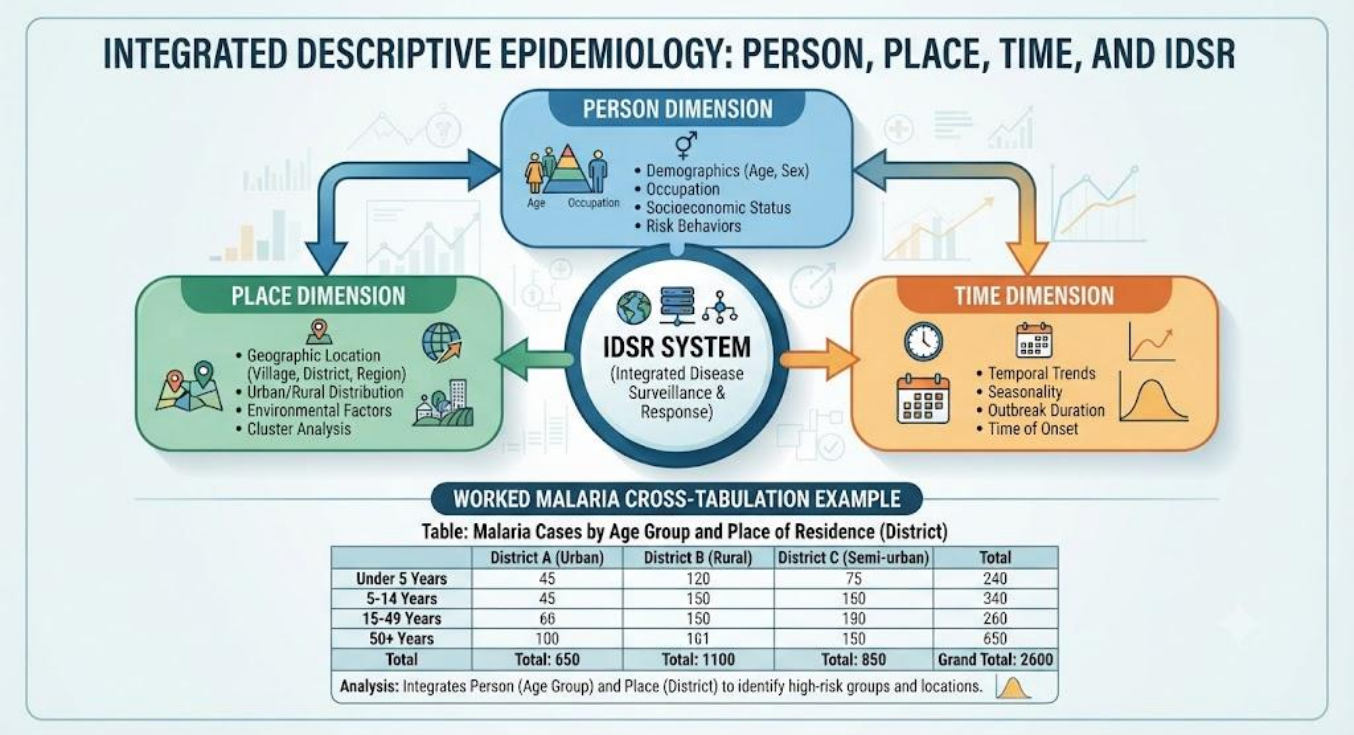
2.4.3 Descriptive epidemiology in the Nigerian context

Descriptive epidemiology is the operational backbone of disease control in Nigeria, applied continuously through the IDSR system, the NDHS and MICS surveys, and disease-specific surveillance programmes for malaria, HIV, tuberculosis, polio, and Lassa fever. Each of these systems generates routine person, place, and time data that public health authorities use to

monitor trends, detect anomalies, and direct resources. The northern meningitis belt seasonal pattern, the southern malaria transmission gradient, the geographic concentration of Lassa fever in specific states, and the age-specific patterns of child mortality across Nigeria geopolitical zones are all products of sustained descriptive epidemiological surveillance.

A persistent challenge in the Nigerian context is the completeness and quality of the underlying data: incomplete facility reporting, weak vital registration (covered in earlier demography courses), and limited laboratory confirmation capacity all constrain the precision of descriptive epidemiological analysis. Strengthening data systems, including electronic health information systems, laboratory networks, and community-based surveillance through CHEWs, is therefore not a peripheral technical concern but a direct determinant of how effectively descriptive epidemiology can fulfil its role in guiding disease prevention and control across the country.

Fill in the blank: A persistent challenge to descriptive epidemiology in Nigeria is the completeness and _____ of the underlying surveillance data, constrained by incomplete facility reporting, weak vital registration, and limited laboratory confirmation capacity.



	District A (Urban)	District B (Rural)	District C (Semi-urban)	Total
Under 5 Years	45	120	75	240
5-14 Years	45	150	150	340
15-49 Years	66	150	190	260
50+ Years	100	161	150	650
Total	Total: 650	Total: 1100	Total: 850	Grand Total: 2600

Figure 2.4: Integrating person, place, and time in Nigerian disease surveillance

Pilot questions 2.4

1. Why is integrating person, place, and time more powerful than examining each dimension separately?
2. How does the IDSR system use person, place, and time data to detect outbreaks?
3. What does it mean to say that descriptive data generates hypotheses rather than proving causation?
4. Name three Nigerian surveillance or survey systems that generate descriptive epidemiological data.
5. Name two challenges to the quality of descriptive epidemiological data in Nigeria.

Series Summary

This Series examined descriptive epidemiology through its three classical dimensions. By person, age and sex were established as the most powerful descriptive characteristics, supplemented by socioeconomic, ethnic, behavioural, and genetic and biological host factors, each contributing to the observed pattern of disease in a population. By place, disease variation was examined from the international scale through national and sub-national patterns to local-area clustering, with disease mapping introduced as a powerful descriptive and hypothesis-generating tool tracing its origins to John Snow cholera map.

By time, secular trends, cyclical and seasonal variation, and point versus propagated epidemics were distinguished, with the epidemic curve introduced as the central tool for visualising and interpreting time-pattern data. The Series concluded by demonstrating that the full power of descriptive epidemiology emerges from integrating all three dimensions simultaneously, as practised in Nigeria IDSR and national survey systems, while cautioning that descriptive patterns generate hypotheses rather than establish causation, setting the stage for the analytical methods examined in Series 3 (SLOs 2.1 to 2.7).

Glossary of Terms

- **Choropleth map:** a map that shades geographic areas according to a measured rate or value, such as disease incidence by state.
- **Cyclical variation:** disease patterns that recur at intervals longer than one year, often reflecting the build-up and depletion of population susceptibility.
- **Epidemic curve:** a histogram of case counts plotted against time of onset, used to infer the likely mode of disease transmission during an outbreak.
- **Point epidemic:** an outbreak resulting from a group exposure to a common source over a brief period, producing a sharp rise and fall in cases on the epidemic curve.

- **Propagated epidemic:** an outbreak spread through person-to-person transmission, producing successive waves of cases spaced roughly one incubation period apart.
- **Secular trend:** a gradual change in disease occurrence over years or decades, reflecting underlying changes in risk factors, healthcare, or population structure.
- **Seasonal variation:** regular within-year fluctuation in disease occurrence, typically driven by climate-related changes in vector abundance or behaviour.
- **Social gradient:** the consistent pattern in which lower socioeconomic groups experience higher rates of disease and mortality across virtually all health conditions.
- **Spot map:** a map marking the geographic location of individual disease cases, used to visually identify clusters.
- **Spatial clustering statistics:** formal statistical tests for whether observed geographic clustering of disease cases exceeds what would be expected by chance.

Concept Check Questions [Series 2]

Objective questions

1. _____ is the single most powerful person characteristic in descriptive epidemiology, as nearly every disease shows a characteristic pattern by this variable. (Linked to SLO 2.1)
2. The _____ gradient in health describes the consistent pattern in which lower socioeconomic groups experience higher disease and mortality rates. (Linked to SLO 2.2)
3. _____ maps shade geographic areas according to disease rate, allowing comparison across administrative units. (Linked to SLO 2.4)
4. _____ epidemics in the northern meningitis belt of Nigeria cluster during the dry, dusty harmattan season. (Linked to SLO 2.5)
5. A point epidemic produces a sharp rise and fall in case numbers on the epidemic curve, while a _____ epidemic produces successive waves through person-to-person transmission. (Linked to SLO 2.6)
6. Association observed in descriptive data does not establish _____ , since patterns may reflect confounding, reverse causation, or chance. (Linked to SLO 2.7)

Short-answer questions

7. Explain how age and sex influence disease occurrence, giving one Nigerian example of each. (Linked to SLO 2.1)
8. Distinguish between secular trends, cyclical variation, and seasonal variation, giving a Nigerian example of each. (Linked to SLO 2.5)
9. Explain how the shape of an epidemic curve helps distinguish a point-source outbreak from a propagated outbreak. (Linked to SLO 2.6)

Long-answer questions

10. Discuss descriptive epidemiology by place, covering international, national, and local-area variation, and explain the role of disease mapping. (Linked to SLOs 2.3–2.4)

11. Evaluate the integration of person, place, and time data in Nigerian disease surveillance, using the IDSR system as an example. (Linked to SLOs 2.5–2.7)

Answers to Concept Check Questions [Series 2]

Objective questions

6. Age.
7. Social.
8. Choropleth.
9. Meningitis.
10. Propagated.
11. Causation.

Short-answer questions

12. Age: malaria and measles cluster in young children with less acquired immunity, while cardiovascular disease and cancer increase with age due to cumulative exposure. Sex: malaria mortality is higher in pregnant women due to pregnancy-related immune changes; road traffic injury mortality is substantially higher in men due to occupational exposure and risk behaviour.
13. Secular trend: gradual change over years or decades, e.g. the declining trend in Nigerian child mortality since the 1990s. Cyclical variation: recurrence at intervals longer than a year, e.g. multi-year measles outbreak cycles in under-vaccinated populations. Seasonal variation: regular within-year fluctuation, e.g. malaria transmission peaking during and after the rainy season.
14. A sharp, narrow single peak suggests a point-source exposure, since all cases cluster around the average incubation period after a single brief exposure event. A series of declining peaks spaced roughly one incubation period apart suggests propagated, person-to-person transmission, as each wave of new cases is generated by the previous wave.

Long-answer questions

15. **Basic response:** International: malaria concentrated in sub-Saharan Africa due to climate and vector ecology; NCD burden proportionally greater in high-income ageing populations. National: Nigeria malaria transmission higher in the humid south, lower and seasonal in the drier north; maternal mortality higher in north-east and north-west zones. Local: small-area analysis using GIS identifies neighbourhood-level clusters, e.g. near a contaminated water source. Mapping: spot maps (individual case locations, e.g. John Snow cholera map), choropleth maps (shaded administrative areas by rate), GIS overlay (case data against environmental and demographic layers).

Value-added response: Place-based descriptive epidemiology is the foundation of geographically targeted intervention in Nigeria: indoor residual spraying campaigns are prioritised in high-transmission southern states, while seasonal malaria chemoprevention targets the Sahel states with the most pronounced seasonal transmission peak. Without rigorous place-based descriptive data, resource allocation would default to uniform national distribution, which is both inefficient and inequitable given the substantial geographic variation in disease burden across Nigeria.

16. **Basic response:** IDSR collects person, place, and time data on notifiable conditions continuously: a sudden case increase in a specific LGA (place) signals a possible outbreak; a cluster in an unexpected age group (person) suggests an unusual transmission pattern; a rise outside the expected season (time) suggests an emerging threat. Cross-tabulating all three dimensions, such as age-specific malaria incidence by state and month, reveals patterns invisible in any single dimension and directs the precise targeting of interventions such as seasonal chemoprevention.

Value-added response: The integration of person, place, and time within IDSR exemplifies why descriptive epidemiology, despite generating only hypotheses rather than proof of causation, remains operationally indispensable: it is the early warning system that triggers the analytical and outbreak investigation methods covered in later Series. The persistent data quality challenges in Nigeria, incomplete reporting and weak vital registration, directly limit

the sensitivity of this early warning function, meaning investment in surveillance data quality is itself a disease control intervention.

Answers to Pilot Questions [Series 2]

Part 2.1

11. Because nearly every disease shows a characteristic age pattern, reflecting differences in exposure, physiological susceptibility, immune status, and cumulative risk over the life course.
12. Any two of: higher malaria mortality in pregnant women; cervical cancer affecting only women; prostate cancer affecting only men; higher road traffic injury mortality in men.
13. The social gradient in health is the consistent pattern in which lower socioeconomic groups experience higher rates of disease and mortality across virtually all health conditions, observed across countries and time periods.
14. G6PD deficiency causes haemolysis specifically when triggered by certain drugs or foods, meaning the genetic susceptibility only manifests as disease in the presence of the specific environmental trigger.
15. Any three of: immune status, nutritional status, physiological state (such as pregnancy), genetic susceptibility.

Part 2.2

1. Because malaria transmission depends on the Anopheles mosquito vector, which thrives in the warm, humid climate and abundant breeding sites characteristic of tropical and sub-tropical regions including sub-Saharan Africa.
2. Any two of: malaria transmission intensity (higher in humid south, lower and seasonal in drier north); maternal mortality (higher in north-east and north-west zones due to weaker

health service access and female education); Lassa fever (concentrated in specific southern and Middle Belt states where the rodent reservoir is endemic).

3. Urban areas typically have better formal healthcare and infrastructure access but face overcrowding and chronic disease risk; rural areas have more limited healthcare access and higher infectious and vector-borne disease rates. Complication in Nigeria: large informal urban settlements combine urban population density with rural-level service deficits, blurring this simple distinction.
4. A spot map marks the location of individual disease cases, useful for visually identifying clusters. A choropleth map shades entire geographic areas (such as states) according to a disease rate, useful for comparing burden across administrative units.
5. Any one of: mapping malaria transmission intensity to target indoor residual spraying and bed net distribution; mapping polio case locations to identify transmission chains and target vaccination campaigns; mapping cases during a cholera or Lassa fever outbreak to identify the source and guide response.

Part 2.3

6. A secular trend is a gradual change in disease occurrence over years or decades. Example: the global decline in smallpox incidence leading to eradication in 1980.
7. Cyclical variation refers to disease patterns recurring at intervals longer than one year, often due to building and depletion of population susceptibility. Seasonal variation refers to regular within-year fluctuation, typically driven by climate-related changes in vector abundance or behaviour.
8. Meningitis epidemics peak during the dry, dusty harmattan season (roughly November to April), when the dry air and dust are believed to damage the nasopharyngeal mucosa, facilitating bacterial invasion.
9. A point-source epidemic results from exposure to a common source over a brief period, producing a sharp, narrow rise and fall in cases. A propagated epidemic spreads through person-to-person transmission, producing successive waves of cases spaced roughly one incubation period apart.

10. A sharp single peak suggests point-source exposure; a series of declining peaks spaced one incubation period apart suggests person-to-person propagated transmission; a prolonged irregular pattern may suggest an ongoing continuous common-source exposure.

Part 2.4

11. Because cross-tabulating all three dimensions reveals patterns that none would expose alone, such as a disease being concentrated in a specific age group, in specific states, during a specific season, which has direct implications for the precise targeting of interventions.
12. IDSR collects person, place, and time data continuously on notifiable conditions; unusual deviations in any dimension, a sudden case increase in a specific area, a cluster in an unexpected age group, or a rise outside the expected season, serve as triggers for further investigation.
13. It means that descriptive patterns suggest plausible explanations for further testing but do not by themselves prove that an apparent association reflects a genuine causal relationship, since the pattern could also result from confounding, reverse causation, or chance.
14. Any three of: the Integrated Disease Surveillance and Response (IDSR) system; the Nigeria Demographic and Health Survey (NDHS); the Multiple Indicator Cluster Survey (MICS); disease-specific surveillance for malaria, HIV, tuberculosis, polio, or Lassa fever.
15. Any two of: incomplete facility reporting; weak vital registration; limited laboratory confirmation capacity.

References and Attributions [Series 2]

Textual references

1. Gordis, L. (2014). Epidemiology (5th ed.). Elsevier Saunders.
2. Snow, J. (1855). On the mode of communication of cholera (2nd ed.). John Churchill.
3. Nigeria Centre for Disease Control. (2023). Technical guidelines for integrated disease surveillance and response (3rd ed.). NCDC.
4. National Open University of Nigeria (NOUN). (2023). Introduction to general epidemiology course material. NOUN Press.

Figures, Plates, Tables, and Boxes

1. Figure 2.1: Person characteristics in descriptive epidemiology Attribution: AI generated using prompt "Generate a four-category diagram of person characteristics in descriptive epidemiology with Nigerian examples for each category." Suggested OER search string: "descriptive epidemiology person age sex socioeconomic gradient genetic host factors Nigeria OER"
2. Figure 2.2: Disease mapping methods and geographic variation in Nigeria Attribution: AI generated using prompt "Generate a two-panel diagram showing three disease mapping types and a simplified Nigeria map with malaria transmission intensity shading." Suggested OER search string: "disease mapping spot map choropleth GIS malaria transmission Nigeria geographic variation OER"
3. Figure 2.3: Patterns of disease occurrence over time Attribution: AI generated using prompt "Generate a two-panel diagram showing point-source versus propagated epidemic curve shapes, and a twelve-month seasonal calendar of major Nigerian disease patterns." Suggested OER search string: "epidemic curve point source propagated outbreak seasonal disease pattern Nigeria malaria meningitis cholera OER"
4. Figure 2.4: Integrating person, place, and time in Nigerian disease surveillance Attribution: AI generated using prompt "Generate a diagram showing the integration of person, place, and time dimensions in descriptive epidemiology with the IDSR system at

the centre and a worked malaria cross-tabulation example." Suggested OER search string: "integrating person place time descriptive epidemiology IDSR Nigeria malaria surveillance hypothesis OER"

Course code: COM 308

Course title: Introduction to General Epidemiology

Course credit load: 2 Units

Series 3: Epidemiological Methods and Applications

- **Part 3.1: Measures of Disease Frequency and Association**
  - Sub Part 3.1.1: Review of incidence, prevalence, and disease frequency
  - Sub Part 3.1.2: Measures of association: relative risk and odds ratio
  - Sub Part 3.1.3: Interpreting measures of association
- **Part 3.2: The Cohort Study**
  - Sub Part 3.2.1: Design and conduct of cohort studies
  - Sub Part 3.2.2: Strengths and limitations of cohort studies
  - Sub Part 3.2.3: Worked example of a cohort study
- **Part 3.3: The Case-Control Study**
  - Sub Part 3.3.1: Design and conduct of case-control studies
  - Sub Part 3.3.2: Strengths and limitations of case-control studies
  - Sub Part 3.3.3: Worked example of a case-control study
- **Part 3.4: Bias, Confounding, and Causal Inference**
  - Sub Part 3.4.1: Selection and information bias
  - Sub Part 3.4.2: Confounding and its control
  - Sub Part 3.4.3: Criteria for causal inference

Introduction

Descriptive epidemiology, examined in the previous Series, generates hypotheses about disease causation by characterising patterns of disease by person, place, and time. Analytical epidemiology takes the next step: it formally tests those hypotheses using study designs that compare disease frequency between groups with different exposures, quantifying the strength of any association and assessing whether that association is likely to reflect a genuine causal relationship.

The aim of this Series is to introduce the principal analytical epidemiological methods: the measures of association that quantify exposure-disease relationships, the cohort and case-control study designs, and the concepts of bias, confounding, and causal inference that determine whether an observed association can be interpreted as causal.

We shall commence by reviewing measures of disease frequency and introducing the measures of association: relative risk and odds ratio. Next, we will examine the cohort study in depth. Moving on, we will examine the case-control study in depth. Finally, we will close by addressing bias, confounding, and the criteria for causal inference that determine how an observed association should be interpreted.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 3.1** calculate and interpret the relative risk and the odds ratio as measures of association,
- **SLO 3.2** describe the design, conduct, and analysis of a cohort study,
- **SLO 3.3** explain the strengths and limitations of the cohort study design,
- **SLO 3.4** describe the design, conduct, and analysis of a case-control study,
- **SLO 3.5** explain the strengths and limitations of the case-control study design,
- **SLO 3.6** distinguish between selection bias, information bias, and confounding, and

- **SLO 3.7** apply the Bradford Hill criteria to assess whether an observed association is likely to be causal.

3.1 Measures of Disease Frequency and Association

3.1.1 Review of incidence, prevalence, and disease frequency

As established in earlier coursework, **incidence** measures the occurrence of new cases of disease in a population at risk over a defined period, while **prevalence** measures the existence of cases at a point or period in time. These measures of disease frequency are the building blocks from which **measures of association** are constructed: by calculating disease frequency separately in an exposed group and an unexposed (or differently exposed) group, and then comparing the two frequencies, epidemiologists can quantify whether and how strongly an exposure is associated with a disease outcome.

The choice of which frequency measure to use as the basis for comparison depends on the study design. Cohort studies, which follow populations forward in time, can directly calculate and compare **cumulative incidence** or **incidence rate** between exposed and unexposed groups, generating the **relative risk**. Case-control studies, which work backward from existing cases, cannot directly calculate incidence, and instead generate the **odds ratio** as an approximation of the relative risk. Understanding this distinction is essential to interpreting the measures of association produced by each study design correctly.

Fill in the blank: Measures of _____ are constructed by calculating disease frequency separately in an exposed group and an unexposed group, then comparing the two frequencies to quantify whether and how strongly an exposure is related to a disease outcome.

3.1.2 Measures of association: relative risk and odds ratio

The **relative risk (RR)**, also called the risk ratio, is calculated as: RR = incidence in the exposed group ÷ incidence in the unexposed group. It directly answers the question: how many times more (or less) likely are exposed individuals to develop the disease compared with unexposed

individuals? An RR of 1 indicates no association between exposure and outcome; an RR greater than 1 indicates the exposure is associated with increased risk; an RR less than 1 indicates the exposure is associated with decreased (protective) risk. The relative risk can only be calculated directly in study designs, such as cohort studies, where the incidence of disease in each exposure group is known.

The **odds ratio (OR)** is calculated as: OR = (odds of exposure among cases) ÷ (odds of exposure among controls), which is mathematically equivalent to (a × d) ÷ (b × c) in a standard 2×2 table where a is exposed cases, b is unexposed cases, c is exposed controls, and d is unexposed controls. The odds ratio is used in case-control studies, where the true incidence of disease cannot be calculated because the investigator has selected the number of cases and controls rather than observing them arising naturally from a defined population. When the disease under study is rare (occurring in less than approximately 10% of the population), the odds ratio closely approximates the relative risk, an important property that makes case-control study results interpretable in the same direction and approximate magnitude as cohort study results.

Fill in the blank: The odds ratio is calculated as (a × d) ÷ (b × c) in a standard 2×2 table; when the disease under study is rare, the odds ratio closely approximates the _____ , making case-control results comparable in direction and magnitude to cohort study results.

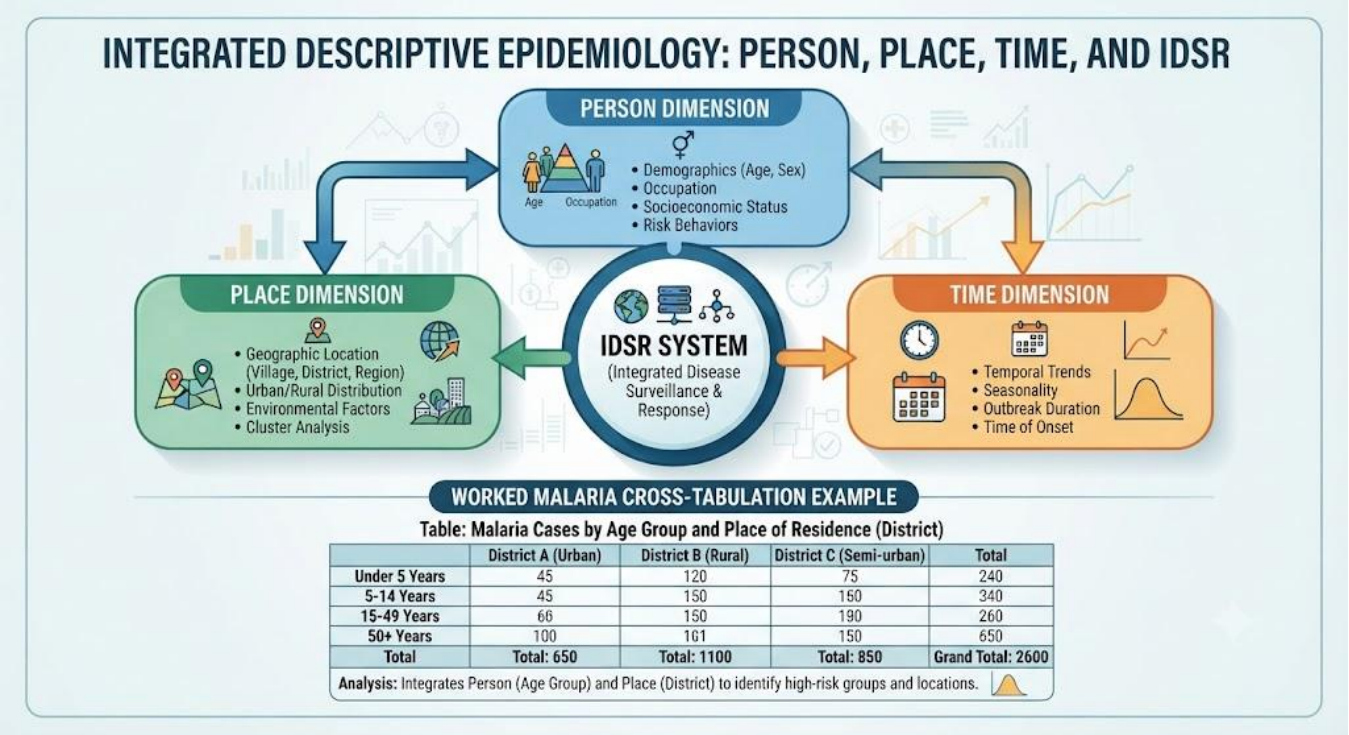
3.1.3 Interpreting measures of association

Beyond the point estimate of the relative risk or odds ratio, epidemiological interpretation requires assessing the precision and statistical significance of the estimate. The **confidence interval (CI)** (typically a 95% confidence interval) provides a range of values within which the true population value is likely to lie, given the sampling variability of the study. A 95% CI that does not include 1.0 indicates that the observed association is statistically significant at the conventional threshold (the null value of no association, RR or OR = 1, can be excluded with 95% confidence). A wide confidence interval indicates greater uncertainty, often reflecting a small sample size, while a narrow confidence interval indicates a more precise estimate.

Beyond statistical significance, the **magnitude** of the relative risk or odds ratio carries important clinical and public health meaning. An RR of 1.2 indicates a modest 20% increase in risk, which

may still be important at a population level if the exposure is common, while an RR of 10 indicates a tenfold increase in risk, a very strong association rarely seen outside of major causal relationships (such as smoking and lung cancer, where RR exceeds 10 in heavy smokers). The **attributable risk** (the absolute difference in incidence between exposed and unexposed groups) complements the relative measure by indicating the actual burden of disease attributable to the exposure, which is essential for public health priority-setting since a high relative risk for a rare exposure may produce a smaller absolute disease burden than a modest relative risk for a common exposure.

Fill in the blank: A 95% confidence interval that does not include the value _____ indicates that the observed association between exposure and outcome is statistically significant at the conventional threshold.



	District A (Urban)	District B (Rural)	District C (Semi-urban)	Total
Under 5 Years	45	120	75	240
5-14 Years	45	150	160	340
15-49 Years	66	150	190	260
50+ Years	100	161	150	650
Total	Total: 650	Total: 1100	Total: 850	Grand Total: 2600

Figure 3.1: Measures of association and their interpretation

Pilot questions 3.1

1. Write the formula for the relative risk.
2. Write the formula for the odds ratio using a 2x2 table.

3. When does the odds ratio closely approximate the relative risk?
4. What does a 95% confidence interval that excludes 1.0 indicate?
5. Distinguish between relative risk and attributable risk.

3.2 The Cohort Study

3.2.1 Design and conduct of cohort studies

A **cohort study** begins with a group of disease-free individuals, classifies them by exposure status, and follows them forward in time to compare the incidence of disease between exposed and unexposed groups. In a **prospective cohort study**, the exposure is assessed at the start of the study and participants are followed forward into the future, as in the Framingham Heart Study, which has followed participants since 1948. In a **retrospective (historical) cohort study**, the investigator uses existing records to reconstruct exposure and outcome status that have already occurred, following the cohort logic forward through historical records rather than real time, often used when long follow-up periods are needed but cannot practically be waited for prospectively.

The conduct of a cohort study follows a defined sequence: defining the study population and the exposure of interest; ascertaining exposure status accurately at baseline (through records, biomarkers, or interview); following the cohort over time with minimal loss to follow-up; ascertaining the outcome (disease occurrence) using a consistent, ideally blinded, method in both exposed and unexposed groups; and calculating and comparing incidence between the groups to derive the relative risk. The temporal sequence (exposure measured before outcome occurs) is the defining structural strength of the cohort design, since it directly establishes that the exposure preceded the disease, addressing one of the necessary conditions for causal inference.

Fill in the blank: In a _____ cohort study, exposure is assessed at the start of the study and participants are followed forward into the future, as exemplified by the Framingham Heart Study.

3.2.2 Strengths and limitations of cohort studies

Cohort studies offer several distinctive strengths. They establish **temporal sequence** directly (exposure is confirmed to precede outcome), they can study **multiple outcomes** from a single exposure (since the cohort is followed for all health events, not just one predefined disease), they allow direct calculation of **incidence** and therefore the relative risk, and they are particularly well suited to studying **rare exposures** (by deliberately recruiting individuals with the exposure of interest, such as occupational cohorts exposed to a specific chemical). Prospective cohort studies also minimise **recall bias**, since exposure is measured before the outcome occurs, when participants have no reason to selectively recall or misreport their exposure history.

The principal limitations of cohort studies are practical and resource-related. They are generally **expensive and time-consuming**, particularly for diseases with long latency periods (decades may be required to observe sufficient cases of cancer or cardiovascular disease). They are **inefficient for rare diseases**, since a very large cohort must be followed to accrue a sufficient number of cases of an uncommon outcome. They are vulnerable to **loss to follow-up** (participants who drop out of the study, move away, or die from unrelated causes, potentially introducing bias if loss to follow-up is related to both exposure and outcome). These limitations explain why the case-control design, examined in Part 3.3, remains the preferred approach for studying rare diseases.

Fill in the blank: Cohort studies are _____ for studying rare diseases because a very large cohort must be followed for a long period to accrue a sufficient number of cases of an uncommon outcome.

3.2.3 Worked example of a cohort study

Consider a hypothetical prospective cohort study examining whether exposure to indoor air pollution from solid cooking fuel increases the risk of chronic respiratory disease. A cohort of 2,000 women using solid fuel (exposed) and 2,000 women using clean cooking fuel (unexposed) is followed for 10 years, with all participants free of respiratory disease at baseline. At the end of follow-up, 240 cases of chronic respiratory disease occur among the solid-fuel users and 80 cases occur among the clean-fuel users.

Incidence among exposed = 240 / 2,000 = 0.12 (12%). Incidence among unexposed = 80 / 2,000 = 0.04 (4%). Relative risk = 0.12 ÷ 0.04 = 3.0. This result indicates that women using solid cooking fuel had three times the risk of developing chronic respiratory disease over the 10-year follow-up period compared with women using clean cooking fuel. If the 95% confidence interval for this RR (for example, 2.1 to 4.3) excludes 1.0, the association is statistically significant, providing strong evidence (alongside other criteria for causal inference, covered in Part 3.4) that household air pollution exposure increases the risk of chronic respiratory disease, directly relevant to Nigeria clean cooking fuel policy priorities established in earlier environmental health coursework.

Fill in the blank: In the worked cohort study example, the incidence of chronic respiratory disease was 12% among solid-fuel users and 4% among clean-fuel users, giving a relative risk of _____ , meaning exposed women had three times the risk of unexposed women.

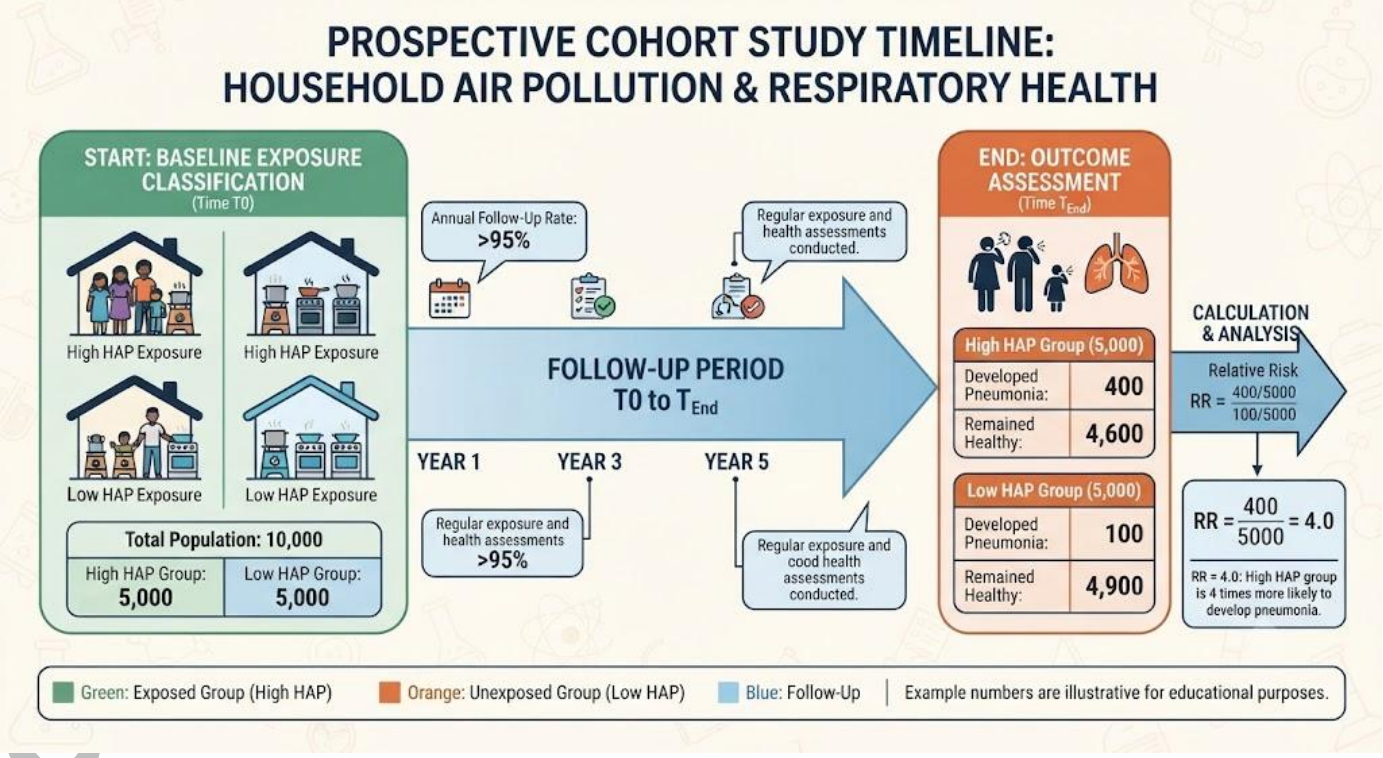


Figure 3.2: Structure and worked example of a cohort study

Pilot questions 3.2

1. Distinguish between a prospective and a retrospective cohort study.
2. Name the defined sequence of steps in conducting a cohort study.
3. Name three strengths of the cohort study design.
4. Why are cohort studies inefficient for studying rare diseases?
5. In a cohort study with 150 cases among 3,000 exposed and 50 cases among 3,000 unexposed, calculate the relative risk.

3.3 The Case-Control Study

3.3.1 Design and conduct of case-control studies

A **case-control study** begins with a group of individuals who already have the disease of interest (the **cases**) and a comparison group of individuals without the disease (the **controls**), and works backward in time to compare the prior exposure history between the two groups. This retrospective approach makes the case-control design fundamentally different in structure from the cohort study, though both are observational designs that test hypotheses about exposure-disease association.

The conduct of a case-control study requires careful attention to several methodological steps: defining a precise **case definition** (typically based on clinical and laboratory criteria) and identifying cases through hospital records, disease registries, or population surveillance; selecting an appropriate **control group** that represents the exposure distribution in the population from which the cases arose (controls may be drawn from the general population, from hospital patients with other conditions, or from neighbours or relatives of cases, each approach carrying different strengths and limitations); and ascertaining **exposure history** in both groups using a consistent method, typically interview, record review, or biomarker measurement, applied identically to cases and controls to avoid differential measurement.

Fill in the blank: A case-control study begins with individuals who already have the disease of interest (cases) and a comparison group without the disease (controls), then works backward in time to compare prior _____ history between the two groups.

3.3.2 Strengths and limitations of case-control studies

Case-control studies offer substantial practical advantages: they are **efficient for rare diseases** (since cases are deliberately selected rather than awaited within a large cohort), they are generally **faster and less expensive** than cohort studies (no lengthy follow-up period is required), and they can examine **multiple exposures** for a single disease outcome (since exposure history is collected broadly rather than being limited to one predefined exposure, as is often the case in a cohort study designed around a specific hypothesis). These efficiency advantages make the case-control design the method of choice for investigating rare diseases and for generating initial evidence on a newly suspected exposure-disease relationship.

The principal limitations of case-control studies relate to their retrospective structure. **Recall bias** is a significant concern: cases, having experienced the disease, may recall or report their exposure history differently from controls (for example, a person with lung cancer may search their memory more thoroughly for past smoking or occupational exposures than a healthy control would). **Selection bias** can arise if controls do not accurately represent the exposure distribution of the population from which cases arose. Case-control studies also cannot directly calculate incidence (since the proportion of cases and controls is set by the investigator rather than reflecting natural disease occurrence), meaning the odds ratio rather than the relative risk is the only measure of association available, requiring the rare disease assumption discussed in Part 3.1 for the odds ratio to approximate the relative risk closely.

Fill in the blank: _____ bias is a significant concern in case-control studies because cases, having experienced the disease, may recall or report their exposure history differently from controls who have not experienced the disease.

3.3.3 Worked example of a case-control study

Consider a hypothetical case-control study investigating whether a history of unprotected sun exposure is associated with skin cancer. The study enrols 150 confirmed skin cancer cases from a dermatology clinic and 300 controls without skin cancer, matched for age and sex, drawn from the same clinic population attending for unrelated conditions. Exposure history (regular unprotected sun exposure over the preceding 20 years) is assessed by structured interview in both groups. Among the cases, 90 report a history of regular unprotected sun exposure and 60 do not; among the controls, 90 report such exposure and 210 do not.

Using the 2×2 table notation: a (exposed cases) = 90, b (unexposed cases) = 60, c (exposed controls) = 90, d (unexposed controls) = 210. Odds ratio = (a × d) ÷ (b × c) = (90 × 210) ÷ (60 × 90) = 18,900 ÷ 5,400 = 3.5. This result indicates that the odds of having a history of regular unprotected sun exposure were 3.5 times higher among skin cancer cases than among controls, providing evidence consistent with a causal association between unprotected sun exposure and skin cancer risk, an association well established in the global epidemiological literature and increasingly relevant to skin cancer surveillance in Nigeria as population ageing and changing outdoor occupational patterns evolve.

Fill in the blank: In the worked case-control study example, the odds ratio was calculated as (90 × 210) ÷ (60 × 90), giving a value of _____ , indicating the odds of sun exposure were higher among skin cancer cases than among controls.

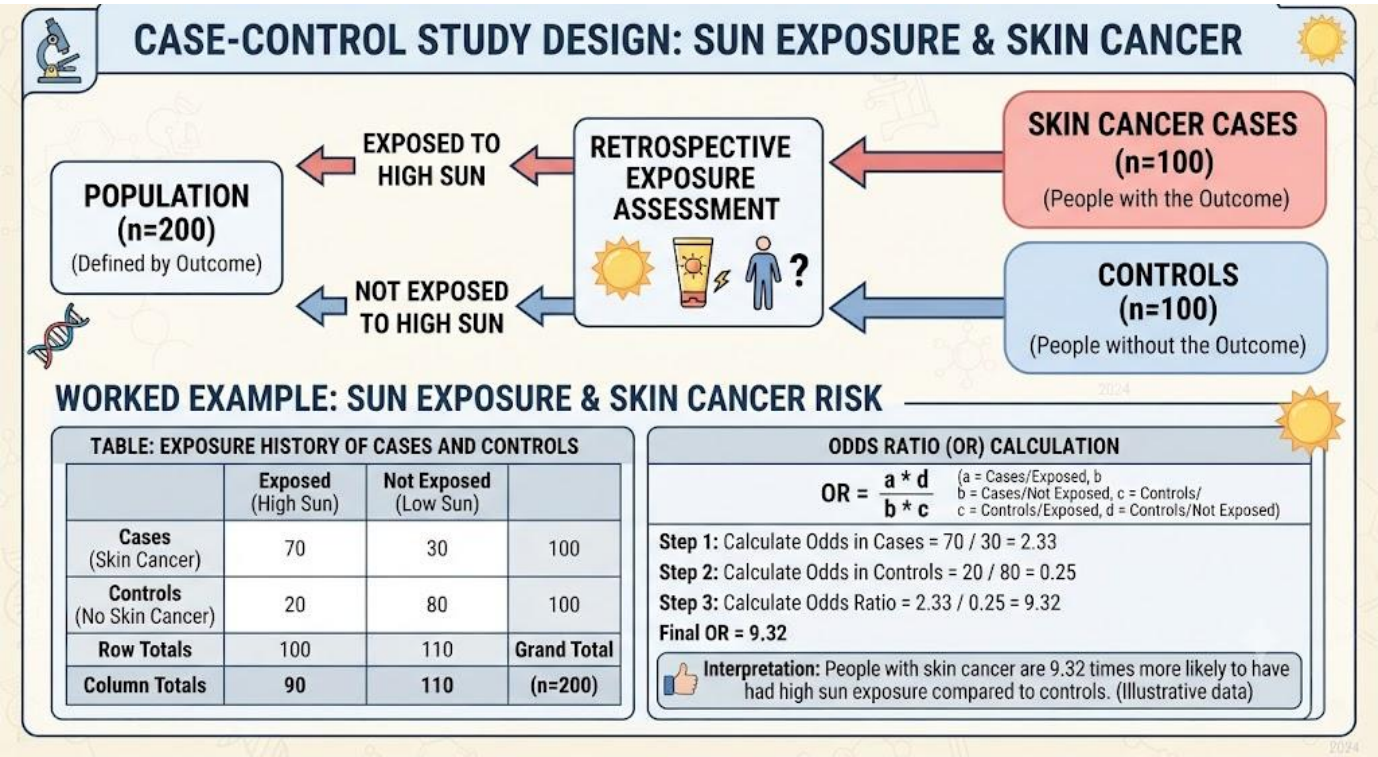


Figure 3.3: Structure and worked example of a case-control study

Pilot questions 3.3

1. Define a case-control study and explain its basic structure.
2. Name three considerations in selecting an appropriate control group.
3. Name three strengths of the case-control study design.
4. What is recall bias and why is it a particular concern in case-control studies?
5. In a case-control study with a=80, b=40, c=50, d=230, calculate the odds ratio.

3.4 Bias, Confounding, and Causal Inference

3.4.1 Selection and information bias

Bias is a systematic error in the design, conduct, or analysis of a study that produces an incorrect estimate of the true exposure-disease association. Unlike random error (which decreases with larger sample size and is reflected in the width of the confidence interval), bias is not reduced by

increasing sample size and instead reflects a flaw in the study methodology itself. **Selection bias** arises when the individuals selected for the study (whether participants in a cohort or cases and controls in a case-control study) are not representative of the population to which the findings are meant to apply, distorting the observed association. Examples include the healthy worker effect (employed cohorts tending to be healthier than the general population, biasing occupational exposure studies) and inappropriate control selection in case-control studies.

Information bias (also called measurement or misclassification bias) arises from inaccurate measurement of exposure or outcome. **Recall bias** (discussed in Part 3.3) is a specific form of information bias common in case-control studies. **Interviewer bias** occurs when data collectors probe cases and controls differently, often unconsciously, based on knowledge of disease status. **Differential misclassification** occurs when the degree of measurement error differs between comparison groups, distorting the association in an unpredictable direction; **non-differential misclassification** occurs when measurement error is equal across groups, which generally biases the association toward the null (making a true association appear weaker than it is). Minimising information bias requires standardised, ideally blinded, measurement procedures applied identically across all study groups.

Fill in the blank: _____ bias arises when individuals selected for a study are not representative of the population to which the findings are meant to apply, distorting the observed exposure-disease association.

3.4.2 Confounding and its control

Confounding occurs when a third factor is associated with both the exposure and the outcome, but is not a step in the causal pathway between them, creating a spurious or distorted appearance of association. For a factor to be a confounder, it must satisfy three conditions: it must be associated with the exposure, it must be an independent risk factor for the outcome (associated with the outcome even in the absence of the exposure), and it must not be an intermediate step on the causal pathway from exposure to outcome. A classic example is age as a confounder in studies of physical inactivity and cardiovascular disease: older people are both less physically

active and at higher inherent cardiovascular risk, so failing to account for age could make physical inactivity appear more strongly associated with cardiovascular disease than it truly is.

Confounding can be controlled at the design stage through **randomisation** (in experimental studies, distributing both known and unknown confounders evenly between groups), **restriction** (limiting the study to a single level of the confounding variable, such as studying only non-smokers to remove smoking as a confounder), or **matching** (selecting controls or comparison groups with the same distribution of the confounding variable as the cases or exposed group). Confounding can also be controlled at the analysis stage through **stratification** (analysing the association separately within strata of the confounder) or **multivariable statistical adjustment** (using regression methods to estimate the exposure-disease association while holding the confounder constant). Failing to account for confounding is one of the most common sources of misleading conclusions in observational epidemiology.

Fill in the blank: For a factor to be a confounder, it must be associated with the exposure, be an independent risk factor for the outcome, and must not be an intermediate step on the _____ pathway between exposure and outcome.

3.4.3 Criteria for causal inference

Establishing that an observed association reflects a genuine causal relationship, rather than chance, bias, or confounding, requires systematic assessment against established criteria. **Sir Austin Bradford Hill** proposed a widely used set of considerations in 1965, often called the **Bradford Hill criteria**: **strength of association** (stronger associations, large RR or OR, are less likely to be fully explained by undetected bias or confounding); **consistency** (the association is observed repeatedly by different investigators, in different populations, using different study designs); **specificity** (the exposure is associated with a specific outcome rather than a wide range of unrelated outcomes, though this criterion is less useful for multifactorial chronic diseases); **temporality** (the exposure must precede the outcome, the only criterion considered absolutely necessary for causation).

Additional Bradford Hill considerations include: **biological gradient (dose-response)** (increasing exposure is associated with increasing risk); **biological plausibility** (the association

is consistent with current understanding of disease mechanisms); **coherence** (the association does not conflict with the known natural history of the disease); **experimental evidence** (intervention to remove or reduce the exposure reduces disease occurrence, the strongest available evidence); and **analogy** (similar exposures are known to produce similar effects). No single criterion is sufficient or strictly required (except temporality), and causal inference requires a judgement integrating the totality of evidence against all applicable criteria, rather than a mechanical checklist applied in isolation.

Fill in the blank: Among the Bradford Hill criteria for causal inference, _____ (the exposure must precede the outcome) is the only criterion considered absolutely necessary for establishing a causal relationship.

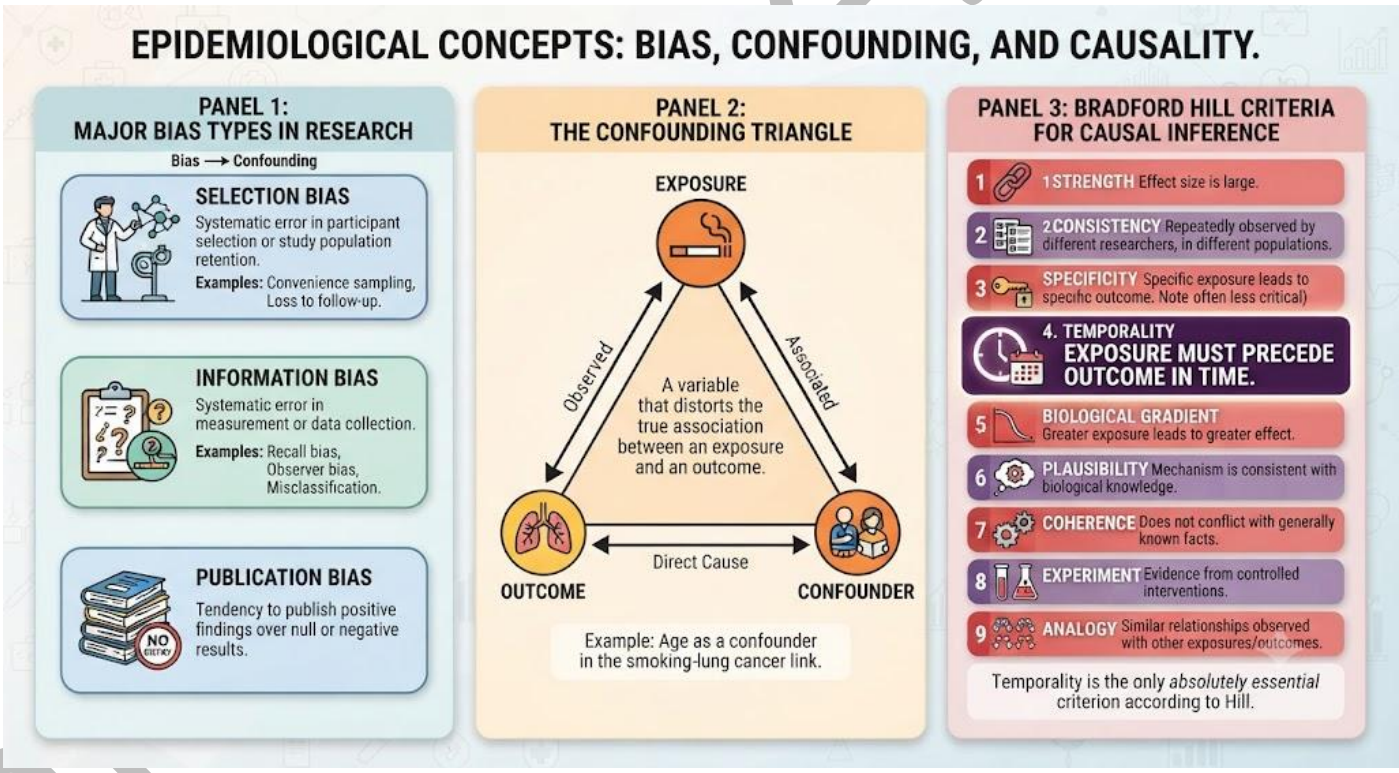


Figure 3.4: Bias, confounding, and the Bradford Hill criteria for causal inference

Pilot questions 3.4

1. Distinguish between bias and random error.
2. Define selection bias and give one example.

3. What are the three conditions a factor must satisfy to be a confounder?
4. Name three methods for controlling confounding.
5. Which Bradford Hill criterion is considered absolutely necessary for causal inference and why?

Series Summary

This Series introduced the principal methods of analytical epidemiology. Measures of association, the relative risk and the odds ratio, were defined and distinguished according to the study design from which each arises, with confidence intervals and attributable risk introduced as complementary measures of precision and absolute burden. The cohort study was examined in depth, including its prospective and retrospective forms, its strengths in establishing temporal sequence and studying multiple outcomes, and its limitations in cost, duration, and inefficiency for rare diseases, illustrated through a worked household air pollution example.

The case-control study was examined as the efficient alternative for rare disease investigation, with attention to case definition, control selection, and the particular vulnerability of this design to recall bias, illustrated through a worked skin cancer example. The Series concluded by addressing the threats to valid causal inference, selection bias, information bias, and confounding, and their control through design and analytical methods, before introducing the Bradford Hill criteria as the systematic framework for judging whether an observed association reflects a genuine causal relationship (SLOs 3.1 to 3.7).

Glossary of Terms

- **Bradford Hill criteria:** a set of considerations proposed by Austin Bradford Hill for assessing whether an observed association is likely to be causal, including strength, consistency, temporality, and dose-response.
- **Case-control study:** an observational study design that begins with cases and controls and works backward to compare prior exposure history between the two groups.
- **Cohort study:** an observational study design that begins with a disease-free population classified by exposure status and follows them forward to compare disease incidence.
- **Confounding:** a distortion of the observed exposure-disease association caused by a third factor associated with both exposure and outcome but not on the causal pathway.
- **Confidence interval:** a range of values within which the true population value is likely to lie, given the sampling variability of a study, typically calculated at the 95% level.
- **Information bias:** systematic error arising from inaccurate measurement of exposure or outcome, including recall bias and interviewer bias.
- **Odds ratio:** a measure of association calculated as the odds of exposure among cases divided by the odds of exposure among controls, used in case-control studies.
- **Relative risk:** a measure of association calculated as the incidence in the exposed group divided by the incidence in the unexposed group, used in cohort studies.
- **Recall bias:** a form of information bias in which cases and controls recall or report past exposure differently, often because cases search their memory more thoroughly.
- **Selection bias:** systematic error arising when study participants are not representative of the population to which findings are meant to apply.

Concept Check Questions [Series 3]

Objective questions

1. The relative risk is calculated as incidence in the exposed group divided by incidence in the _____ group. (Linked to SLO 3.1)
2. The odds ratio closely approximates the relative risk when the disease under study is _____ . (Linked to SLO 3.1)
3. In a _____ cohort study, exposure is assessed at the start of the study and participants are followed forward into the future. (Linked to SLO 3.2)
4. A case-control study begins with cases and controls and works backward to compare prior _____ history between the two groups. (Linked to SLO 3.4)
5. _____ bias arises when study participants are not representative of the population to which findings are meant to apply. (Linked to SLO 3.6)
6. Among the Bradford Hill criteria, _____ is the only criterion considered absolutely necessary for causal inference. (Linked to SLO 3.7)

Short-answer questions

7. Distinguish between the relative risk and the odds ratio, stating which study design produces each. (Linked to SLO 3.1)
8. Name three strengths and two limitations of the cohort study design. (Linked to SLOs 3.2–3.3)
9. Distinguish between selection bias, information bias, and confounding. (Linked to SLO 3.6)

Long-answer questions

10. Discuss the cohort and case-control study designs, comparing their structure, strengths, and limitations, with reference to worked examples. (Linked to SLOs 3.2–3.5)
11. Evaluate the threats to causal inference in observational epidemiology and explain how the Bradford Hill criteria support a judgement of causation. (Linked to SLOs 3.6–3.7)

Answers to Concept Check Questions [Series 3]

Objective questions

6. Unexposed.
7. Rare.
8. Prospective.
9. Exposure.
10. Selection.
11. Temporality.

Short-answer questions

12. Relative risk = incidence in exposed / incidence in unexposed; produced by cohort studies, which can directly measure incidence. Odds ratio = odds of exposure in cases / odds of exposure in controls; produced by case-control studies, which cannot measure incidence directly since case and control numbers are set by the investigator.
13. Strengths: establishes temporal sequence directly, can study multiple outcomes from one exposure, allows direct calculation of incidence and relative risk. Limitations: expensive and time-consuming, especially for diseases with long latency; inefficient for studying rare diseases since a very large cohort is needed.
14. Selection bias: study participants are not representative of the population to which findings should apply. Information bias: exposure or outcome is measured inaccurately, e.g. recall bias. Confounding: a third factor associated with both exposure and outcome, not on the causal pathway, distorts the observed association.

Long-answer questions

15. **Basic response:** Cohort study: begins with disease-free population classified by exposure, follows forward in time, calculates incidence and relative risk directly; example, household air pollution and respiratory disease, RR=3.0. Strengths: temporal sequence, multiple outcomes, direct incidence calculation, minimal recall bias. Limitations: expensive, time-consuming, inefficient for rare disease, vulnerable to loss to

follow-up. Case-control study: begins with cases and controls, works backward to compare exposure history, calculates odds ratio; example, sun exposure and skin cancer, OR=3.5. Strengths: efficient for rare disease, faster, less expensive, can study multiple exposures. Limitations: recall bias, selection bias in control selection, cannot directly calculate incidence.

Value-added response: The choice between cohort and case-control design is rarely about which is methodologically superior in the abstract; it is a practical trade-off determined by the disease frequency and the research question. A rare cancer is best studied by case-control design (efficiently identifying the limited number of existing cases), while a common exposure with multiple possible outcomes, such as household air pollution, is well suited to cohort design, which captures the full range of resulting health effects rather than requiring a separate study for each.

16. **Basic response:** Threats: selection bias (unrepresentative participants), information bias (inaccurate measurement, recall bias, interviewer bias, misclassification), and confounding (a third factor distorting the association). Confounding control: randomisation, restriction, matching at design stage; stratification and multivariable adjustment at analysis stage. Bradford Hill criteria: strength, consistency, temporality (necessary), biological gradient, plausibility, coherence, experimental evidence, analogy, specificity.

Value-added response: No observational study can eliminate all threats to causal inference through design alone; this is why the Bradford Hill criteria function as a structured judgement framework rather than a definitive test. A single well-designed cohort study showing a strong, dose-dependent association with biological plausibility provides far more confidence than a single small case-control study with a marginal association, even though both are technically "evidence" of association. Epidemiologists must weigh the totality and quality of evidence, not simply count studies showing significance.

Answers to Pilot Questions [Series 3]

Part 3.1

11. RR = incidence in exposed / incidence in unexposed.
12. OR = (a × d) / (b × c), where a = exposed cases, b = unexposed cases, c = exposed controls, d = unexposed controls.
13. When the disease under study is rare, occurring in less than approximately 10% of the population.
14. It indicates that the observed association is statistically significant, since the null value of no association (RR or OR = 1) can be excluded with 95% confidence.
15. Relative risk is a ratio measure, expressing how many times more likely the exposed group is to develop disease. Attributable risk is an absolute measure, expressing the actual difference in incidence between exposed and unexposed groups, indicating the disease burden attributable to the exposure.

Part 3.2

1. A prospective cohort study assesses exposure at the start of the study and follows participants forward into the future in real time. A retrospective cohort study uses existing records to reconstruct exposure and outcome status that have already occurred.
2. Defining the study population and exposure of interest; ascertaining exposure status accurately at baseline; following the cohort with minimal loss to follow-up; ascertaining outcome consistently in both groups; calculating and comparing incidence to derive the relative risk.
3. Any three of: establishes temporal sequence directly, can study multiple outcomes from a single exposure, allows direct calculation of incidence, well suited to rare exposures, minimises recall bias.
4. Because a very large cohort must be followed, often for a long period, to accrue a sufficient number of cases of an uncommon outcome, making the study inefficient in terms of time and resources relative to the number of cases obtained.

5. Incidence exposed = 150/3,000 = 0.05. Incidence unexposed = 50/3,000 = 0.0167. RR = 0.05 / 0.0167 ≈ 3.0.

Part 3.3

6. A case-control study begins with individuals who already have the disease (cases) and a comparison group without the disease (controls), then works backward in time to compare the prior exposure history between the two groups.
7. Any three of: controls should represent the exposure distribution of the population from which cases arose; controls may be drawn from the general population, hospital patients with other conditions, or relatives/neighbours of cases; the source of controls affects comparability and the risk of selection bias.
8. Any three of: efficient for rare diseases, faster and less expensive than cohort studies, can examine multiple exposures for one outcome, useful for generating initial evidence on a newly suspected association.
9. Recall bias is differential recall or reporting of past exposure between cases and controls. It is a particular concern in case-control studies because cases, having experienced the disease, may search their memory more thoroughly for past exposures than controls who have not experienced the disease.
10. OR = (80 × 230) / (40 × 50) = 18,400 / 2,000 = 9.2.

Part 3.4

11. Bias is systematic error arising from a flaw in study design, conduct, or analysis, and is not reduced by increasing sample size. Random error is due to chance sampling variability, decreases with larger sample size, and is reflected in the width of the confidence interval.
12. Selection bias is systematic error arising when study participants are not representative of the population to which findings should apply. Example: the healthy worker effect, in

which employed cohorts tend to be healthier than the general population, biasing occupational exposure studies.

13. It must be associated with the exposure; it must be an independent risk factor for the outcome; it must not be an intermediate step on the causal pathway between exposure and outcome.
14. Any three of: randomisation, restriction, matching (at the design stage); stratification, multivariable statistical adjustment (at the analysis stage).
15. Temporality, because the exposure must precede the outcome for a causal relationship to be logically possible; without temporality, no other criterion (strength, consistency, dose-response) can establish causation.

References and Attributions [Series 3]

Textual references

1. Gordis, L. (2014). Epidemiology (5th ed.). Elsevier Saunders.
2. Hill, A. B. (1965). The environment and disease: Association or causation? Proceedings of the Royal Society of Medicine, 58(5), 295-300.
3. Rothman, K. J., Greenland, S., & Lash, T. L. (2008). Modern epidemiology (3rd ed.). Lippincott Williams & Wilkins.
4. National Open University of Nigeria (NOUN). (2023). Introduction to general epidemiology course material. NOUN Press.

Figures, Plates, Tables, and Boxes

1. Figure 3.1: Measures of association and their interpretation Attribution: AI generated using prompt "Generate a diagram showing a 2x2 epidemiological table with RR and OR formulas, and a number line illustrating association interpretation with a confidence interval example." Suggested OER search string: "2x2 table relative risk odds ratio confidence interval epidemiology measures of association OER"
2. Figure 3.2: Structure and worked example of a cohort study Attribution: AI generated using prompt "Generate a cohort study timeline diagram from baseline exposure classification through follow-up to outcome, with the household air pollution worked example numbers displayed." Suggested OER search string: "cohort study design timeline prospective retrospective relative risk worked example household air pollution OER"
3. Figure 3.3: Structure and worked example of a case-control study Attribution: AI generated using prompt "Generate a case-control study structure diagram working backward from cases and controls to exposure history, with the skin cancer worked example 2x2 table and odds ratio calculation." Suggested OER search string: "case-control study design retrospective odds ratio worked example skin cancer sun exposure OER"

4. Figure 3.4: Bias, confounding, and the Bradford Hill criteria for causal inference
   Attribution: AI generated using prompt "Generate a three-panel diagram showing bias types, the confounding triangle, and the Bradford Hill criteria for causal inference with temporality highlighted." Suggested OER search string: "selection bias information bias confounding triangle Bradford Hill criteria causal inference epidemiology OER"

Course code: COM 308

Course title: Introduction to General Epidemiology

Course credit load: 2 Units

Series 4: Investigation of Epidemics and Screening in Disease Control

- **Part 4.1: Recognising and Confirming an Epidemic**
  - Sub Part 4.1.1: Definitions: epidemic, outbreak, endemic, and pandemic
  - Sub Part 4.1.2: Establishing the existence of an epidemic
  - Sub Part 4.1.3: Establishing the case definition
- **Part 4.2: Steps in Epidemic Investigation**
  - Sub Part 4.2.1: Preparation, verification, and case finding
  - Sub Part 4.2.2: Descriptive analysis and hypothesis generation
  - Sub Part 4.2.3: Hypothesis testing and implementing control measures
- **Part 4.3: Principles of Screening in Disease Control**
  - Sub Part 4.3.1: Definition and purposes of screening
  - Sub Part 4.3.2: Criteria for a good screening programme
  - Sub Part 4.3.3: Validity of screening tests: sensitivity and specificity
- **Part 4.4: Evaluating Screening Tests and Programmes in Nigeria**
  - Sub Part 4.4.1: Predictive values and the effect of disease prevalence
  - Sub Part 4.4.2: Biases in screening evaluation
  - Sub Part 4.4.3: Screening programmes in the Nigerian health system

Introduction

When disease occurrence rises unexpectedly, public health authorities must act quickly and systematically to identify the cause, contain the spread, and protect the population. Epidemic investigation applies the descriptive and analytical methods examined in earlier Series to this urgent, real-time task. A complementary discipline, screening, applies a different epidemiological logic: detecting disease before symptoms appear, when early intervention offers the greatest chance of preventing serious illness or death.

The aim of this Series is to examine the systematic steps of epidemic investigation, from recognising that an epidemic exists through to implementing and evaluating control measures, and to introduce the principles of screening in disease control, including the validity measures used to evaluate screening tests.

We shall commence by defining epidemic terminology and examining how an epidemic is recognised and confirmed. Next, we will work through the systematic steps of epidemic investigation. Moving on, we will introduce the principles and criteria of screening in disease control. Finally, we will close by examining the validity of screening tests and the application of screening programmes within the Nigerian health system.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 4.1** distinguish between epidemic, outbreak, endemic, and pandemic disease occurrence,
- **SLO 4.2** describe how an epidemic is recognised, confirmed, and defined through a case definition,
- **SLO 4.3** list and explain the systematic steps of epidemic investigation,
- **SLO 4.4** explain the purposes and criteria of a good screening programme,

- **SLO 4.5** calculate and interpret sensitivity, specificity, and predictive values of a screening test,
- **SLO 4.6** describe the biases that affect screening programme evaluation, and
- **SLO 4.7** describe the application of screening programmes within the Nigerian health system.

4.1 Recognising and Confirming an Epidemic

4.1.1 Definitions: epidemic, outbreak, endemic, and pandemic

An **epidemic** is the occurrence of disease cases in a community or region clearly in excess of the number normally expected in that population over a defined period. An **outbreak** is essentially synonymous with an epidemic but is often used to refer to a more localised or smaller-scale event, such as cases confined to a single institution, village, or event. **Endemic** refers to the constant, usual presence of a disease within a given geographic area or population, the baseline level against which excess (epidemic) occurrence is judged; malaria, for example, is endemic throughout most of Nigeria, meaning its baseline occurrence is high but stable, while a sudden rise above this established baseline would constitute an epidemic.

A **pandemic** is an epidemic that has spread across multiple countries or continents, affecting a large number of people, as exemplified by the COVID-19 pandemic. A **sporadic** disease occurs irregularly and infrequently, without a predictable pattern (such as tetanus, which occurs as isolated cases related to individual wound contamination rather than person-to-person transmission). Correctly distinguishing these terms matters for public health communication and resource mobilisation: declaring an epidemic triggers specific legal, administrative, and resource allocation responses that differ from the routine management of endemic disease.

Fill in the blank: _____ refers to the constant, usual presence of a disease within a given geographic area or population, forming the baseline against which excess (epidemic) occurrence is judged.

4.1.2 Establishing the existence of an epidemic

Establishing that an epidemic exists requires comparing the observed number of cases against the expected number, based on recent historical experience in the same population (typically the average of the preceding several years, adjusted for any known trend or seasonal pattern). Several **epidemic threshold** methods are used in routine surveillance: comparing current case counts against a historical mean plus a defined number of standard deviations (a statistical threshold), or against a graphically derived **epidemic threshold curve** that accounts for expected seasonal variation, widely used for diseases such as meningitis and measles where seasonal baselines are well characterised.

For a newly emerging disease with no historical baseline (such as a novel pathogen), even a single confirmed case, or a small cluster of cases with an unusual clinical presentation or epidemiological link, may be sufficient to declare an outbreak requiring investigation, since the expected baseline occurrence is zero. In Nigeria, the IDSR system establishes **alert and action thresholds** for specific notifiable diseases, providing local health workers with simple, pre-defined criteria (such as a specified number of suspected cases within a specified time period) that trigger automatic reporting and the initiation of investigation, without requiring complex statistical analysis at the point of first detection.

Fill in the blank: For a newly emerging disease with no historical baseline, even a single confirmed case or a small cluster with an unusual clinical presentation may be sufficient to declare an _____ requiring investigation, since the expected baseline occurrence is zero.

4.1.3 Establishing the case definition

A **case definition** is a standardised set of clinical and epidemiological criteria used to determine whether a person should be classified as a case during an outbreak investigation. A well-constructed case definition typically specifies **clinical criteria** (signs and symptoms), **time** (the period during which cases are being counted), **place** (the geographic area of interest), and **person** (characteristics restricting the population, such as age group). Case definitions are commonly stratified into **confirmed** (laboratory-verified), **probable** (meeting clinical criteria with a plausible epidemiological link but lacking laboratory confirmation), and **suspected** (meeting only clinical criteria) categories, reflecting different levels of diagnostic certainty.

The case definition deliberately balances **sensitivity** (capturing as many true cases as possible, achieved by using broad, non-specific clinical criteria) against **specificity** (avoiding the inclusion of non-cases, achieved by using narrower, more specific criteria, often requiring laboratory confirmation). Early in an outbreak investigation, a sensitive (broad) case definition is typically used to maximise case finding and characterise the full extent of the problem; as the investigation matures and laboratory capacity is engaged, the case definition may be refined toward greater specificity to support more precise analytical work. The case definition must remain constant throughout the period of comparison to ensure that any observed trends reflect true changes in disease occurrence rather than changes in case ascertainment criteria.

Fill in the blank: A case definition is commonly stratified into confirmed (laboratory-verified), _____ (meeting clinical criteria with a plausible epidemiological link but lacking laboratory confirmation), and suspected categories.

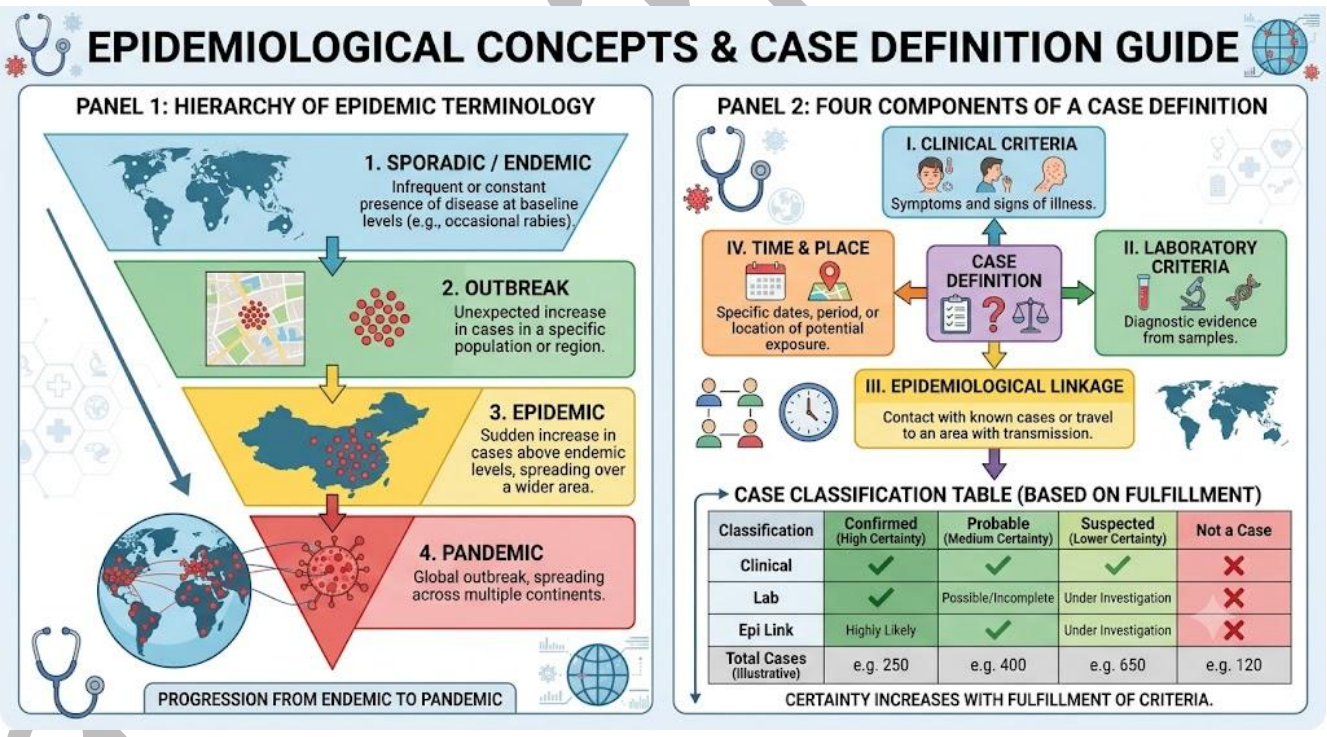


Figure 4.1: Epidemic terminology and the components of a case definition

Pilot questions 4.1

1. Distinguish between an epidemic and an endemic disease.

2. Define a pandemic and give an example.
3. How is the existence of an epidemic established for a disease with a known historical baseline?
4. Name the four components typically specified in a case definition.
5. Why might a sensitive case definition be used early in an outbreak investigation?

4.2 Steps in Epidemic Investigation

4.2.1 Preparation, verification, and case finding

Epidemic investigation follows a systematic sequence of steps, the first of which is **preparation**: assembling the necessary scientific knowledge of the suspected disease, equipment, and personnel before fieldwork begins, and clarifying administrative and logistical arrangements. The second step is **verifying the diagnosis**: confirming that the reported illness is in fact what it has been reported to be, through clinical review and, where possible, laboratory confirmation of a sample of cases, since outbreak investigations have occasionally been initiated based on misdiagnosed or misreported illness.

The third step is **establishing the existence of an outbreak** (comparing observed to expected cases, as covered in Part 4.1), followed by **case finding**: actively searching for additional cases beyond those initially reported, using the established case definition, through methods including active surveillance at health facilities, community case search, and review of laboratory or pharmacy records. Comprehensive case finding is essential because passively reported cases typically represent only a fraction of the true case total, and an incomplete case list will distort the subsequent descriptive and analytical analysis.

Fill in the blank: _____ finding is the systematic search for additional cases beyond those initially reported, using the established case definition, through active surveillance, community search, and review of facility records.

4.2.2 Descriptive analysis and hypothesis generation

Once cases have been identified, the investigation proceeds to **descriptive epidemiology**: characterising the outbreak by person, place, and time (applying the methods established in Series 2), including constructing the epidemic curve to assess the likely mode of transmission (point-source versus propagated, as covered in Series 2). This descriptive characterisation generates initial hypotheses about the source of infection, the mode of transmission, and the population at risk.

Hypothesis generation draws on the descriptive findings, knowledge of the disease agent biological characteristics, and interviews with a sample of cases (asking detailed, open-ended questions about activities, exposures, and contacts in the period preceding illness onset) to develop specific, testable hypotheses about the outbreak source. For example, a cluster of food poisoning cases all linked to attendance at a single wedding reception, with onset times clustering tightly around a common point in the epidemic curve, generates the hypothesis that a specific food item served at that event is the source, which can then be tested by formally comparing the food consumption history of cases and non-cases who attended the same event.

Fill in the blank: _____ generation draws on descriptive findings, knowledge of disease agent characteristics, and detailed interviews with a sample of cases to develop specific, testable explanations for the outbreak source.

4.2.3 Hypothesis testing and implementing control measures

Generated hypotheses are formally tested using the analytical study designs introduced in Series 3, most commonly a **retrospective cohort study** (when the population at risk is a well-defined, enumerable group, such as attendees at a specific event, allowing the calculation of attack rates and relative risk for each suspected exposure) or a **case-control study** (when the population at risk is not well defined, such as a community-wide outbreak, requiring comparison of exposure histories between cases and a comparison group of non-cases). The exposure most strongly and statistically significantly associated with illness, supported by biological plausibility, is accepted as the likely source.

Throughout the investigation, **control measures** should be implemented as soon as a plausible source is identified, without necessarily waiting for the complete analytical confirmation, since

the priority of outbreak response is halting transmission and preventing further illness or death; this principle is exemplified by John Snow removal of the Broad Street pump handle before the causative organism was confirmed. The final steps of investigation are **communicating findings** (to health authorities, the affected community, and, where relevant, the scientific community through a written report) and **maintaining surveillance** to confirm that the outbreak has been controlled and to detect any resurgence.

Fill in the blank: Control measures should be implemented as soon as a plausible source is identified, without necessarily waiting for complete analytical confirmation, since the priority of outbreak response is halting _____ and preventing further illness or death.

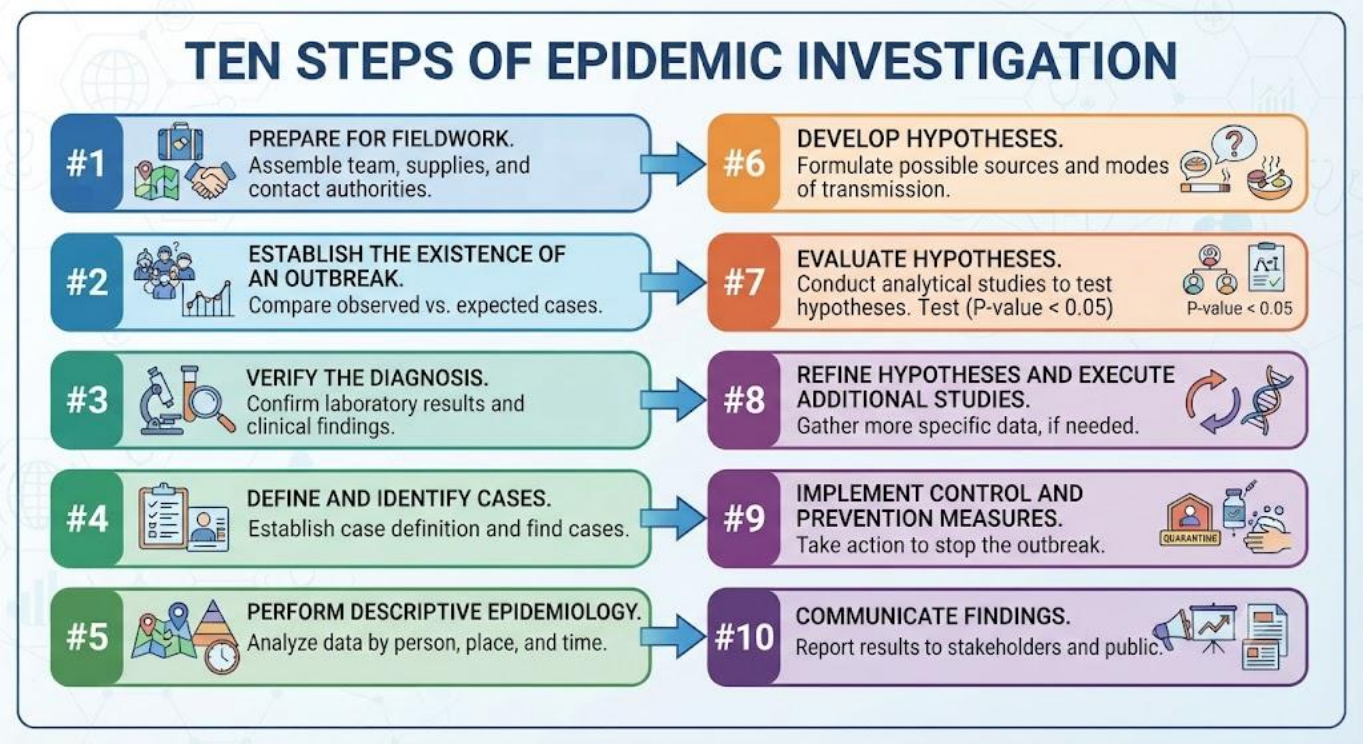


Figure 4.2: The systematic steps of epidemic investigation

Pilot questions 4.2

1. Why is verifying the diagnosis an important early step in epidemic investigation?
2. What is case finding and why is it important?
3. Describe how hypotheses are generated during an outbreak investigation.

4. When is a retrospective cohort study preferred over a case-control study for testing an outbreak hypothesis?
5. Why should control measures be implemented before an investigation is fully complete?

4.3 Principles of Screening in Disease Control

4.3.1 Definition and purposes of screening

Screening is the presumptive identification of unrecognised disease or defect by the application of tests, examinations, or other procedures that can be applied rapidly to apparently healthy populations, distinguishing those who probably have the condition from those who probably do not. Screening is not diagnostic: a positive screening result indicates an increased likelihood of disease, requiring confirmatory diagnostic testing, not a definitive diagnosis. Screening exploits the **subclinical (latent) period** of the natural history of disease (introduced in Series 1), the window during which pathological changes have begun but symptoms have not yet appeared, to detect disease earlier than it would otherwise present clinically.

Screening serves several purposes within disease control: **early detection and treatment** to improve individual prognosis (as in cervical cancer screening, which can detect precancerous changes before invasive cancer develops); **identifying infectious cases** to interrupt transmission (as in HIV or tuberculosis screening); **identifying carriers** of genetic conditions to inform reproductive decisions (as in sickle cell trait screening, particularly relevant given the high prevalence of the sickle cell gene in Nigeria); and **surveillance** to monitor disease prevalence trends in a population over time. Screening can be applied to an entire population (**mass screening**) or targeted to a high-risk subgroup (**selective screening**).

Fill in the blank: Screening is the presumptive identification of unrecognised disease by the application of tests that can be applied rapidly to apparently healthy populations; a positive result requires confirmatory _____ testing, not a definitive diagnosis.

4.3.2 Criteria for a good screening programme

Not every disease is appropriate for screening. The classical **Wilson and Jungner criteria** (1968), still widely used to evaluate the appropriateness of a proposed screening programme, specify that: the condition should be an important health problem; there should be a recognisable latent or early symptomatic stage; the natural history of the disease should be adequately understood; there should be a suitable, acceptable test with established sensitivity and specificity; there should be an accepted, effective treatment available for those identified with the disease; and facilities for diagnosis and treatment should be available to manage the disease once detected.

Additional criteria address programme-level considerations: there should be an agreed policy on whom to treat as patients; the cost of case finding (including diagnosis and treatment of patients diagnosed) should be economically balanced in relation to the possible expenditure on medical care as a whole; case finding should be a continuous process, not a one-time project; and the test itself should be acceptable to the population (causing minimal discomfort, risk, or inconvenience). A screening programme that detects disease but offers no effective treatment, or that is too costly to sustain continuously, fails to satisfy these criteria and may do more harm than good by generating anxiety and resource expenditure without producing health benefit.

Fill in the blank: The Wilson and Jungner criteria specify that there should be an accepted, effective _____ available for those identified with disease, since detecting a condition without the means to address it provides little benefit and may cause harm.

4.3.3 Validity of screening tests: sensitivity and specificity

The validity of a screening test is evaluated by comparing its results against a **gold standard** diagnostic test in a sample of individuals, producing a 2×2 table of true positives (a), false positives (b), false negatives (c), and true negatives (d). **Sensitivity** = a / (a + c), the proportion of individuals who truly have the disease who are correctly identified as positive by the screening test; a highly sensitive test produces few false negatives, making it valuable when missing a case carries serious consequences. **Specificity** = d / (b + d), the proportion of individuals who truly do not have the disease who are correctly identified as negative by the screening test; a highly specific test produces few false positives, making it valuable when a

false-positive result would lead to unnecessary, costly, or harmful further investigation or treatment.

There is typically a **trade-off between sensitivity and specificity**: adjusting the threshold used to define a positive test result in one direction increases sensitivity at the cost of specificity, and vice versa. This trade-off is visualised using a **receiver operating characteristic (ROC) curve**, which plots sensitivity against (1 − specificity) across the range of possible test thresholds, allowing the selection of an optimal threshold balancing the consequences of false negatives against false positives for the specific clinical or public health context. A screening test for a rapidly fatal, highly infectious disease may prioritise sensitivity heavily, while a screening test where false positives lead to invasive and risky confirmatory procedures may prioritise specificity more carefully.

Fill in the blank: Sensitivity equals a divided by (a + c), measuring the proportion of individuals who truly have the disease who are correctly identified as positive, while _____ equals d divided by (b + d), measuring the proportion correctly identified as negative among those without disease.

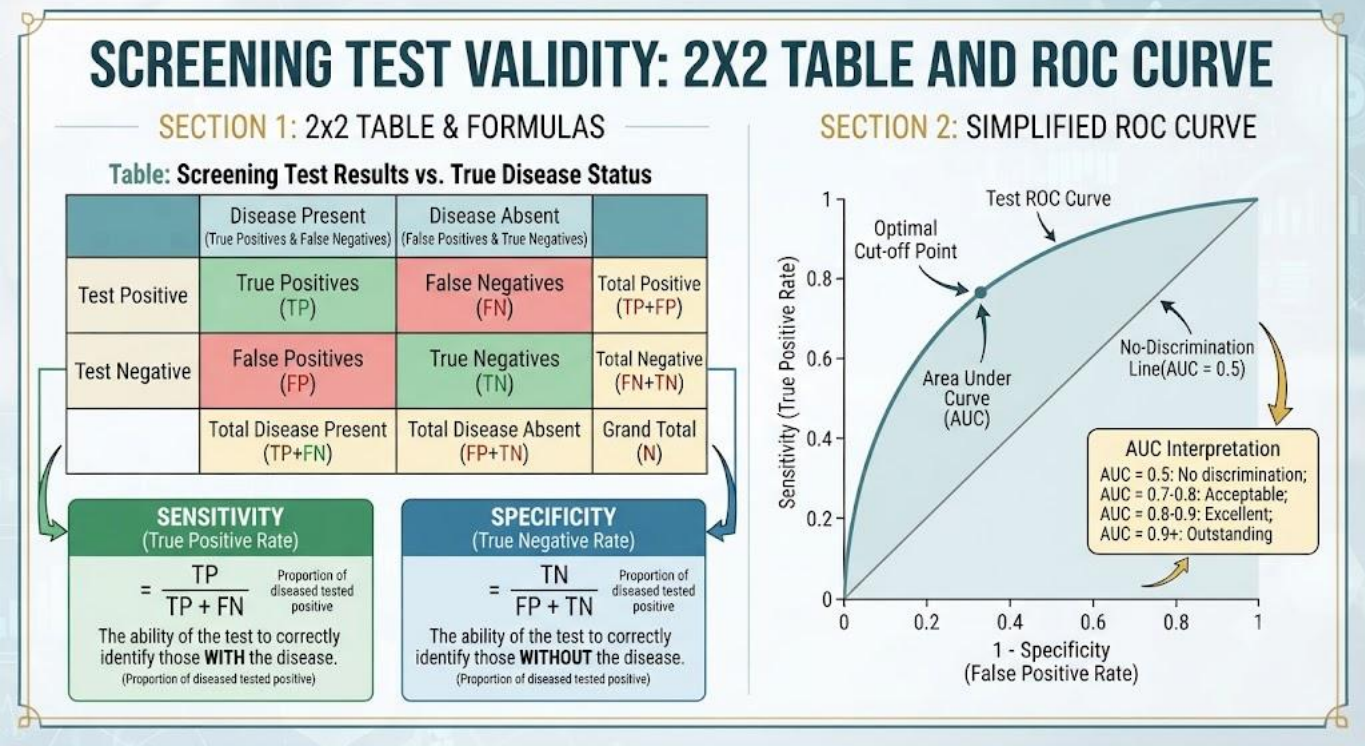


Figure 4.3: Screening test validity: sensitivity, specificity, and the ROC trade-off

Pilot questions 4.3

1. Define screening and explain why a positive screening result is not a diagnosis.
2. Name four of the Wilson and Jungner criteria for a good screening programme.
3. Write the formula for sensitivity and explain what it measures.
4. Write the formula for specificity and explain what it measures.
5. What is the trade-off between sensitivity and specificity, and how is it visualised?

4.4 Evaluating Screening Tests and Programmes in Nigeria

4.4.1 Predictive values and the effect of disease prevalence

While sensitivity and specificity describe the intrinsic accuracy of a test, **predictive values** answer the clinically relevant question: given a test result, what is the probability that the individual truly has (or does not have) the disease? **Positive predictive value (PPV)** = a / (a +

b), the proportion of individuals testing positive who truly have the disease. **Negative predictive value (NPV)** = d / (c + d), the proportion of individuals testing negative who truly do not have the disease. Unlike sensitivity and specificity, which are intrinsic properties of the test itself, predictive values depend heavily on the **prevalence** of the disease in the population being tested.

This prevalence dependence has profound practical implications: the same test, with identical sensitivity and specificity, will have a much lower positive predictive value when applied to a low-prevalence population (most positive results will be false positives, since the much larger pool of true negatives generates a proportionally large number of false positives even at high specificity) than when applied to a high-prevalence population (such as a clinic population already suspected of having the condition). This is why screening programmes are often deliberately targeted to higher-risk subgroups rather than applied universally: targeting raises the effective prevalence in the screened population, improving the positive predictive value and reducing the burden of unnecessary follow-up investigation for false positives.

Fill in the blank: Unlike sensitivity and specificity, which are intrinsic properties of a screening test, _____ values depend heavily on the prevalence of the disease in the population being tested, falling substantially when applied to a low-prevalence population.

4.4.2 Biases in screening evaluation

Evaluating whether a screening programme genuinely improves health outcomes, rather than merely detecting disease earlier without changing the ultimate outcome, is complicated by several characteristic biases. **Lead-time bias** occurs when screening advances the point of diagnosis earlier in the natural history of disease without actually changing the date of death; this creates the appearance of longer survival after diagnosis in screened individuals, even if screening provides no true benefit, because the clock simply started earlier. **Length-time bias** occurs because screening, conducted periodically, preferentially detects slower-growing, less aggressive forms of disease (which have a longer detectable subclinical phase and are therefore more likely to be caught during a screening round) while faster-growing, more aggressive disease is more likely to present clinically between screening rounds, making screen-detected cases appear to have better prognosis even without any treatment benefit.

Selection bias (volunteer bias) arises because individuals who choose to participate in voluntary screening programmes often differ systematically from non-participants in ways related to health outcomes (commonly being more health-conscious and having better baseline health), making comparisons between screened and unscreened populations potentially misleading if this difference is not accounted for. Properly evaluating whether a screening programme reduces disease-specific mortality requires a randomised controlled trial design comparing mortality (not survival time from diagnosis, which is vulnerable to lead-time and length-time bias) between a screened and an unscreened group followed from the point of randomisation, the only design that avoids all three of these characteristic biases.

Fill in the blank: _____ -time bias occurs when screening advances the point of diagnosis earlier in the natural history of disease without changing the actual date of death, creating a false appearance of improved survival in screened individuals.

4.4.3 Screening programmes in the Nigerian health system

Several screening programmes operate within the Nigerian health system, applying the principles established in this Series. **Antenatal screening** includes screening for HIV, syphilis, hepatitis B, and anaemia in pregnant women, enabling early treatment and prevention of mother-to-child transmission. **Newborn screening** for sickle cell disease is increasingly implemented in tertiary facilities, given Nigeria substantial sickle cell disease burden, enabling early initiation of prophylactic treatment (such as penicillin prophylaxis and pneumococcal vaccination) that significantly reduces childhood mortality from sickle cell complications. **Cervical cancer screening** (using visual inspection with acetic acid, Pap smear, or HPV testing) is recommended for women of reproductive age, though coverage remains low nationally.

Challenges to effective screening implementation in Nigeria mirror the Wilson and Jungner criteria: limited diagnostic and treatment infrastructure in many areas means that screening, even when technically feasible, cannot always be followed by the confirmatory diagnosis and treatment that gives screening its value; weak continuity of care means screening is sometimes conducted as episodic campaigns rather than the continuous process the criteria specify; and limited health information systems make it difficult to track screened individuals through to

definitive diagnosis and treatment, undermining programme evaluation. Strengthening these underlying health system functions is therefore a prerequisite for screening programmes to deliver their intended population health benefit, rather than functioning merely as isolated testing events.

Fill in the blank: _____ screening for sickle cell disease is increasingly implemented in Nigerian tertiary facilities, enabling early initiation of prophylactic treatment that significantly reduces childhood mortality from sickle cell complications.

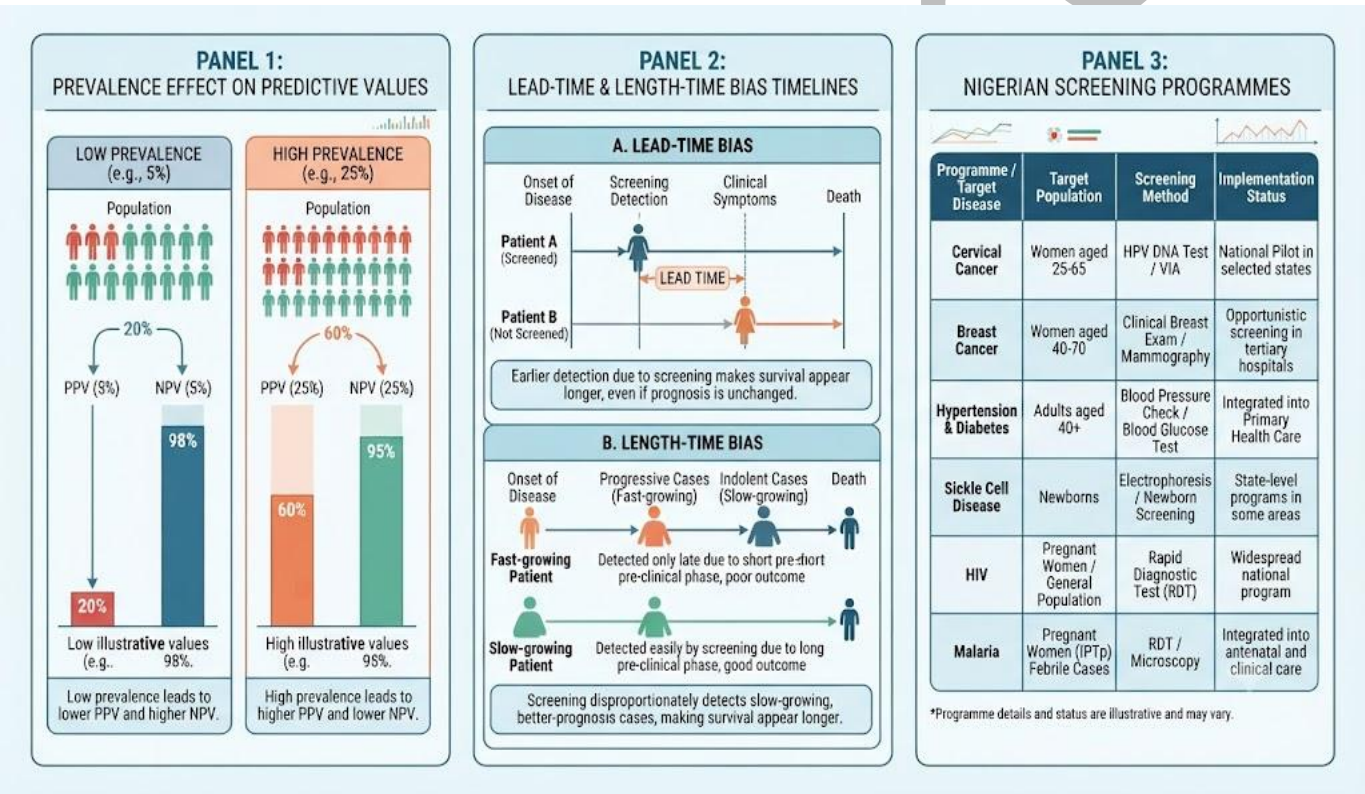


Figure 4.4: Predictive values, screening biases, and Nigerian screening programmes

Pilot questions 4.4

1. Write the formula for positive predictive value and explain why it depends on disease prevalence.
2. Why does targeting screening to a high-risk subgroup improve positive predictive value?
3. Define lead-time bias and explain why it creates a false appearance of improved survival.

4. What study design is needed to properly evaluate whether a screening programme reduces disease-specific mortality, and why?
5. Name three screening programmes operating within the Nigerian health system.

Series Summary

This Series examined two practically essential applications of epidemiology. Epidemic investigation was introduced through the foundational terminology of epidemic, endemic, outbreak, and pandemic, the methods for establishing that an epidemic exists, and the construction of a case definition. The systematic steps of epidemic investigation were traced from preparation and diagnosis verification through case finding, descriptive analysis, hypothesis generation and testing, to the implementation of control measures and communication of findings, with John Snow original investigation serving as the enduring exemplar of acting on evidence before complete confirmation.

Screening was introduced as the presumptive identification of unrecognised disease in apparently healthy populations, governed by the Wilson and Jungner criteria for appropriate programme design. The validity measures of sensitivity and specificity were defined and distinguished from the prevalence-dependent predictive values, and the characteristic biases of screening evaluation, lead-time bias, length-time bias, and selection bias, were examined as threats to valid assessment of screening benefit. The Series concluded by surveying screening programmes within the Nigerian health system and the health system prerequisites required for screening to deliver genuine population health benefit (SLOs 4.1 to 4.7).

Glossary of Terms

- **Case definition:** a standardised set of clinical and epidemiological criteria used to determine whether a person should be classified as a case during an outbreak investigation.
- **Endemic:** the constant, usual presence of a disease within a given geographic area or population, forming the baseline against which epidemic occurrence is judged.
- **Epidemic:** the occurrence of disease cases in a community clearly in excess of the number normally expected over a defined period.

- **Lead-time bias:** a bias in which screening advances the point of diagnosis without changing the date of death, creating a false appearance of improved survival.
- **Length-time bias:** a bias in which periodic screening preferentially detects slower-growing disease, making screen-detected cases appear to have better prognosis.
- **Negative predictive value:** the proportion of individuals testing negative on a screening test who truly do not have the disease.
- **Pandemic:** an epidemic that has spread across multiple countries or continents, affecting a large number of people.
- **Positive predictive value:** the proportion of individuals testing positive on a screening test who truly have the disease; dependent on disease prevalence.
- **Screening:** the presumptive identification of unrecognised disease by tests applied rapidly to apparently healthy populations, requiring confirmatory diagnosis if positive.
- **Sensitivity:** the proportion of individuals who truly have a disease who are correctly identified as positive by a screening test.
- **Specificity:** the proportion of individuals who truly do not have a disease who are correctly identified as negative by a screening test.
- **Wilson and Jungner criteria:** a set of criteria for evaluating whether a disease and test are appropriate for a screening programme, including disease importance, test validity, and treatment availability.

Concept Check Questions [Series 4]

Objective questions

1. _____ refers to the constant, usual presence of a disease within a given geographic area, forming the baseline against which epidemic occurrence is judged. (Linked to SLO 4.1)
2. A case definition is commonly stratified into confirmed, _____ , and suspected categories. (Linked to SLO 4.2)
3. _____ finding is the systematic search for additional cases beyond those initially reported, using the established case definition. (Linked to SLO 4.3)
4. Sensitivity equals a divided by (a + c), while _____ equals d divided by (b + d). (Linked to SLO 4.5)
5. Unlike sensitivity and specificity, _____ values depend heavily on disease prevalence in the population being tested. (Linked to SLO 4.6)
6. _____ -time bias occurs when screening advances diagnosis without changing the date of death, creating a false appearance of improved survival. (Linked to SLO 4.6)

Short-answer questions

7. Describe the systematic steps of epidemic investigation from case finding through to communicating findings. (Linked to SLO 4.3)
8. Explain the Wilson and Jungner criteria and why a screening programme that fails these criteria may cause more harm than benefit. (Linked to SLO 4.4)
9. Distinguish between lead-time bias and length-time bias in screening evaluation. (Linked to SLO 4.6)

Long-answer questions

10. Discuss the systematic process of epidemic investigation, illustrating with the principles applied in John Snow original cholera investigation. (Linked to SLOs 4.1–4.3)

11. Evaluate screening as a disease control strategy in Nigeria, covering test validity, predictive values, evaluation biases, and current screening programmes. (Linked to SLOs 4.4–4.7)

Answers to Concept Check Questions [Series 4]

Objective questions

6. Endemic.
7. Probable.
8. Case.
9. Specificity.
10. Predictive.
11. Lead.

Short-answer questions

12. Case finding: actively searching for additional cases using the case definition through active surveillance and community search. Descriptive epidemiology: characterising cases by person, place, time, and constructing the epidemic curve. Hypothesis generation: developing testable explanations from descriptive findings and case interviews. Hypothesis testing: using cohort or case-control methods to confirm the source. Implementing control measures: acting promptly once a plausible source is identified. Communicating findings: reporting to health authorities and the affected community.
13. Wilson and Jungner criteria: important health problem, recognisable latent stage, understood natural history, suitable acceptable test, effective treatment available, adequate facilities, agreed treatment policy, economically balanced cost, continuous case finding process. A programme that fails these criteria, for example detecting disease with no effective treatment, may cause harm by generating anxiety and cost without producing health benefit.

14. Lead-time bias occurs when screening advances the point of diagnosis without changing the date of death, creating an artificial appearance of longer survival. Length-time bias occurs because periodic screening preferentially detects slower-growing disease with a longer detectable subclinical phase, making screen-detected cases appear to have better prognosis even without any treatment benefit.

Long-answer questions

15. **Basic response:** Steps: preparation, verify diagnosis, establish existence of outbreak, define and find cases, descriptive epidemiology and epidemic curve construction, generate hypotheses, test hypotheses (cohort or case-control), implement control measures, communicate findings, maintain surveillance. Snow example: verified cholera diagnosis, established outbreak existed through clustering of deaths, used a spot map (descriptive epidemiology by place) to generate the hypothesis that the Broad Street pump was the source, and implemented the control measure (removing the pump handle) before the causative organism was confirmed.

    Value-added response: Snow investigation demonstrates that the systematic steps of epidemic investigation are not merely academic ritual but a practical sequence that produces actionable results under uncertainty. The decision to act (removing the pump handle) before complete scientific confirmation (identification of Vibrio cholerae, which came decades later) exemplifies the core principle that outbreak response prioritises halting transmission over achieving complete certainty, a principle directly applied in every modern Nigerian outbreak response, from cholera to Lassa fever to COVID-19.

16. **Basic response:** Validity: sensitivity = a/(a+c), specificity = d/(b+d), intrinsic test properties. Predictive values: PPV = a/(a+b), NPV = d/(c+d), dependent on prevalence; PPV falls substantially in low-prevalence populations, which is why screening is often targeted to high-risk groups. Biases: lead-time bias (false survival improvement from earlier diagnosis), length-time bias (preferential detection of slow-growing disease), selection bias (volunteers differ systematically from non-participants); RCT comparing mortality from randomisation is the only design avoiding all three. Nigerian programmes:

antenatal HIV/syphilis/hepatitis B screening, newborn sickle cell screening, cervical cancer screening.

Value-added response: Nigeria screening programmes illustrate the gap between technical test validity and genuine population health impact: a test can have excellent sensitivity and specificity, but if diagnostic and treatment infrastructure are inadequate to act on positive results, as the Wilson and Jungner criteria require, screening becomes a costly exercise in detection without benefit. Strengthening Nigeria screening impact requires parallel investment in confirmatory diagnostic capacity and treatment access, not simply expanding the number of people tested.

Answers to Pilot Questions [Series 4]

Part 4.1

11. An epidemic is disease occurrence clearly in excess of the number normally expected in a population over a defined period. An endemic disease is the constant, usual presence of a disease at a stable baseline level within a given area or population.
12. A pandemic is an epidemic that has spread across multiple countries or continents, affecting a large number of people. Example: the COVID-19 pandemic.
13. By comparing the current number of observed cases against the expected number, typically derived from the historical average in the same population over recent years, adjusted for known trend or seasonal pattern, using statistical or graphical threshold methods.
14. Clinical criteria, time, place, and person.
15. A sensitive (broad) case definition maximises case finding and helps characterise the full extent of the problem early in an investigation, when comprehensive case ascertainment is more important than diagnostic precision.

Part 4.2

1. Because outbreak investigations have occasionally been initiated based on misdiagnosed or misreported illness; confirming the diagnosis through clinical review and laboratory testing ensures investigative resources are directed at a genuine health threat.
2. Case finding is the active search for additional cases beyond those initially reported, using the case definition. It is important because passively reported cases typically represent only a fraction of the true case total, and an incomplete case list distorts subsequent analysis.
3. Hypotheses are generated from descriptive findings (person, place, time patterns and the epidemic curve), knowledge of the disease agent characteristics, and detailed open-ended interviews with a sample of cases about their activities and exposures before illness onset.
4. A retrospective cohort study is preferred when the population at risk is a well-defined, enumerable group, such as attendees at a specific event, allowing direct calculation of attack rates and relative risk for suspected exposures.
5. Because the priority of outbreak response is halting transmission and preventing further illness or death; waiting for complete analytical confirmation could allow the outbreak to continue causing preventable harm.

Part 4.3

6. Screening is the presumptive identification of unrecognised disease by rapid tests applied to apparently healthy populations. A positive result is not a diagnosis because it only indicates increased likelihood of disease and must be confirmed by definitive diagnostic testing before treatment decisions are made.
7. Any four of: the condition should be an important health problem; there should be a recognisable latent or early symptomatic stage; the natural history should be adequately understood; there should be a suitable, acceptable test; there should be an accepted, effective treatment available; facilities for diagnosis and treatment should be available; case finding should be continuous.

8. Sensitivity = a / (a + c); it measures the proportion of individuals who truly have the disease who are correctly identified as positive by the test.
9. Specificity = d / (b + d); it measures the proportion of individuals who truly do not have the disease who are correctly identified as negative by the test.
10. Adjusting the test threshold in one direction increases sensitivity at the cost of specificity, and vice versa; this trade-off is visualised using a receiver operating characteristic (ROC) curve, which plots sensitivity against 1 minus specificity across different thresholds.

Part 4.4

11. PPV = a / (a + b); it depends on prevalence because in a low-prevalence population the large pool of true negatives generates a proportionally large number of false positives even at high specificity, lowering the proportion of positive results that are true positives.
12. Targeting a high-risk subgroup raises the effective prevalence of disease in the screened population, which increases the positive predictive value and reduces the burden of unnecessary follow-up investigation generated by false positives.
13. Lead-time bias occurs when screening advances the point of diagnosis earlier in the natural history of disease without changing the actual date of death; this creates a false appearance of longer survival after diagnosis simply because the diagnosis clock started earlier, not because the person actually lived longer.
14. A randomised controlled trial comparing mortality (not survival time from diagnosis) between a screened and unscreened group followed from the point of randomisation, because this is the only design that avoids lead-time bias, length-time bias, and selection bias simultaneously.
15. Any three of: antenatal screening for HIV, syphilis, and hepatitis B; newborn screening for sickle cell disease; cervical cancer screening (VIA, Pap smear, or HPV testing).

References and Attributions [Series 4]

Textual references

1. Gordis, L. (2014). Epidemiology (5th ed.). Elsevier Saunders.
2. Wilson, J. M. G., & Jungner, G. (1968). Principles and practice of screening for disease. WHO Public Health Papers, No. 34.
3. Centers for Disease Control and Prevention. (2012). Principles of epidemiology in public health practice (3rd ed.). CDC.
4. National Open University of Nigeria (NOUN). (2023). Introduction to general epidemiology course material. NOUN Press.

Figures, Plates, Tables, and Boxes

1. Figure 4.1: Epidemic terminology and the components of a case definition Attribution: AI generated using prompt "Generate a two-panel diagram showing the hierarchy of epidemic terminology and the four components of a case definition with confirmed/probable/suspected classification." Suggested OER search string: "epidemic outbreak endemic pandemic case definition confirmed probable suspected epidemiology OER"
2. Figure 4.2: The systematic steps of epidemic investigation Attribution: AI generated using prompt "Generate a ten-step numbered flowchart showing the classical steps of epidemic investigation from preparation through to communicating findings." Suggested OER search string: "steps of epidemic investigation outbreak case finding hypothesis testing control measures CDC OER"
3. Figure 4.3: Screening test validity: sensitivity, specificity, and the ROC trade-off Attribution: AI generated using prompt "Generate a diagram showing a 2x2 screening test validity table with sensitivity and specificity formulas, alongside a simplified ROC curve." Suggested OER search string: "screening test sensitivity specificity 2x2 table ROC curve true positive false negative epidemiology OER"

4. Figure 4.4: Predictive values, screening biases, and Nigerian screening programmes
   Attribution: AI generated using prompt "Generate a three-panel diagram showing the prevalence effect on predictive values, lead-time and length-time bias timelines, and a table of Nigerian screening programmes." Suggested OER search string: "positive predictive value prevalence lead-time bias length-time bias Nigeria screening programmes sickle cell OER"

Course code: COM 308

Course title: Introduction to General Epidemiology

Course credit load: 2 Units

Series 5: Principles of Control of Communicable and Non-Communicable Diseases

- **Part 5.1: General Principles of Disease Control**
  - Sub Part 5.1.1: Concepts of control, elimination, and eradication
  - Sub Part 5.1.2: Strategies for disease control
  - Sub Part 5.1.3: The chain of infection as a basis for control
- **Part 5.2: Control of Communicable Diseases**
  - Sub Part 5.2.1: Control measures directed at the agent and reservoir
  - Sub Part 5.2.2: Control measures directed at transmission
  - Sub Part 5.2.3: Control measures directed at the host
- **Part 5.3: Control of Non-Communicable Diseases**
  - Sub Part 5.3.1: The rising burden of non-communicable disease in Nigeria
  - Sub Part 5.3.2: Population-wide and high-risk approaches to NCD prevention
  - Sub Part 5.3.3: Risk factor control and the WHO Best Buys
- **Part 5.4: Integrated Disease Control in Nigeria**
  - Sub Part 5.4.1: National disease control programmes
  - Sub Part 5.4.2: Health system strengthening for disease control
  - Sub Part 5.4.3: Synthesis: epidemiology as the foundation of disease control

Introduction

This final Series of the course brings together the descriptive, analytical, and applied epidemiological methods examined in earlier Series and directs them toward their ultimate purpose: the control of disease. Whether the threat is an infectious agent transmitted from person to person or a chronic condition arising from cumulative behavioural and environmental risk, epidemiology provides the evidence base that determines where control efforts should be directed and how their effectiveness should be measured.

The aim of this Series is to establish the general principles of disease control, including the distinction between control, elimination, and eradication, to examine the specific control strategies applicable to communicable and non-communicable diseases respectively, and to synthesise these principles within the Nigerian disease control context.

We shall commence by establishing the general principles and terminology of disease control, including the chain of infection model. Next, we will examine control measures specific to communicable diseases, organised around the agent, transmission, and host. Moving on, we will examine the principles of non-communicable disease control, including population-wide and high-risk prevention approaches. Finally, we will close by synthesising disease control within the Nigerian national programme and health system context, concluding the course.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 5.1** distinguish between disease control, elimination, and eradication,
- **SLO 5.2** describe the chain of infection and explain how it guides communicable disease control,
- **SLO 5.3** list and explain control measures directed at the agent, transmission, and host in communicable disease control,
- **SLO 5.4** describe the rising burden of non-communicable disease in Nigeria,

- **SLO 5.5** distinguish between the population-wide and high-risk approaches to disease prevention,
- **SLO 5.6** describe key risk factor control strategies for non-communicable disease, and
- **SLO 5.7** describe how national disease control programmes and health system strengthening apply epidemiological principles in Nigeria.

5.1 General Principles of Disease Control

5.1.1 Concepts of control, elimination, and eradication

Disease control refers to ongoing operations aimed at reducing the incidence, prevalence, morbidity, or mortality of a disease to a locally acceptable level, through deliberate efforts, with continued intervention required to maintain the reduction. Most public health disease programmes operate at the level of control: malaria control in Nigeria reduces disease burden through bed nets, indoor spraying, and treatment, but the disease remains present and would resurge if control measures were withdrawn. **Elimination** refers to the reduction to zero of the incidence of a specified disease in a defined geographic area, achieved through deliberate efforts, with continued measures required to prevent re-establishment of transmission, since the causative agent persists elsewhere in the world or in an environmental reservoir.

Eradication refers to the permanent reduction to zero of the worldwide incidence of infection caused by a specific agent, achieved through deliberate efforts, after which intervention measures are no longer needed because the causative agent itself no longer exists in nature (other than in secure laboratory storage). Smallpox remains the only human disease eradicated to date, declared in 1980 following a coordinated global vaccination campaign. Nigeria achieved wild poliovirus elimination status in 2020, an important regional milestone toward global polio eradication, though continued vaccination is still required to guard against re-importation and to address circulating vaccine-derived poliovirus.

Fill in the blank: _____ refers to the permanent reduction to zero of the worldwide incidence of infection caused by a specific agent, after which intervention measures are no longer needed because the agent no longer exists in nature.

5.1.2 Strategies for disease control

Disease control strategies are organised according to the levels of prevention introduced in Series 1. **Primary prevention** strategies aim to prevent disease occurrence altogether, through health promotion (education, nutrition, behaviour change communication) and specific protection (immunisation, vector control, safe water provision, use of personal protective equipment). **Secondary prevention** strategies aim to detect and treat disease early in its course, through screening (covered in Series 4) and prompt diagnosis and treatment of symptomatic cases to limit progression and onward transmission. **Tertiary prevention** strategies aim to limit disability and restore function in those who have developed disease, through appropriate treatment, rehabilitation, and palliative care.

Effective disease control programmes typically combine multiple strategies operating at different levels simultaneously, rather than relying on a single intervention. The Nigeria malaria control programme exemplifies this integrated approach: primary prevention through long-lasting insecticide-treated nets and indoor residual spraying; targeted primary prevention through seasonal malaria chemoprevention for high-risk children; secondary prevention through prompt diagnosis with rapid diagnostic tests and treatment with artemisinin-based combination therapy; and tertiary prevention through management of severe malaria complications in hospital settings. The relative emphasis placed on each strategy depends on the specific epidemiology of the disease, the resources available, and the stage of the control programme.

Fill in the blank: _____ prevention strategies aim to detect and treat disease early in its course through screening and prompt diagnosis, limiting progression and onward transmission before serious complications develop.

5.1.3 The chain of infection as a basis for control

The **chain of infection** is a model describing the sequence of links required for an infectious disease to spread from one host to another: the **infectious agent** (the causative pathogen), the **reservoir** (the habitat in which the agent normally lives and multiplies, such as humans, animals, or the environment), the **portal of exit** (the route by which the agent leaves the reservoir, such as respiratory secretions or faeces), the **mode of transmission** (direct contact, airborne, vector-borne, vehicle-borne, or faecal-oral), the **portal of entry** (the route by which the agent enters a new host), and the **susceptible host** (an individual lacking sufficient immunity to resist infection).

The fundamental principle of communicable disease control is that breaking any single link in this chain is sufficient to prevent transmission, providing multiple potential points of intervention for any given disease. For malaria: treating infected humans reduces the reservoir; eliminating mosquito breeding sites and using indoor residual spraying interrupts the mode of transmission (vector-borne); and bed nets and chemoprevention protect the susceptible host. This framework, organised by intervention target (agent and reservoir, transmission, and host), structures the practical control measures examined in Part 5.2 for communicable diseases.

Fill in the blank: The fundamental principle of communicable disease control is that breaking any single _____ in the chain of infection is sufficient to prevent transmission, providing multiple potential points of intervention for any given disease.

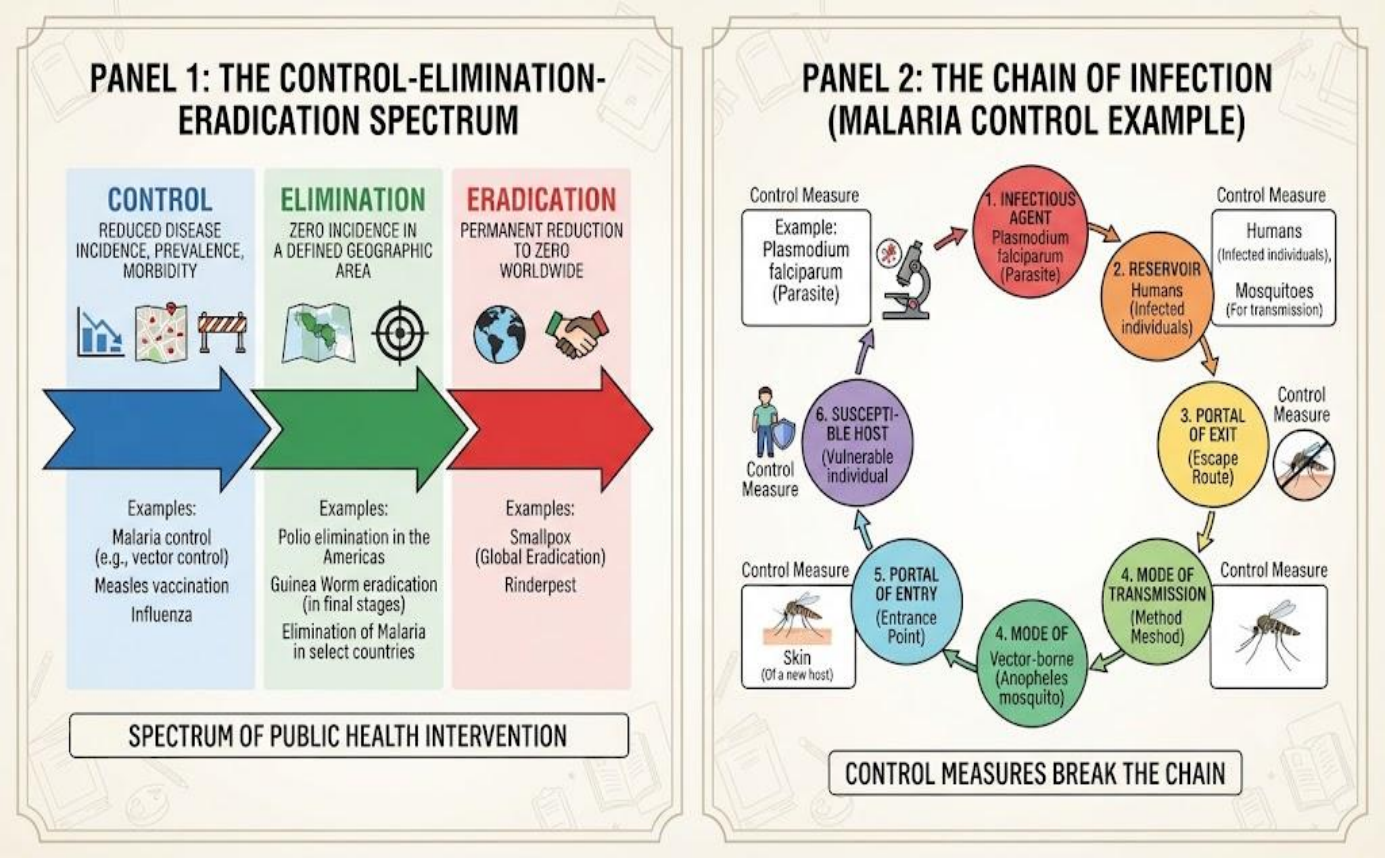


Figure 5.1: Disease control concepts and the chain of infection

Pilot questions 5.1

1. Distinguish between disease control, elimination, and eradication.
2. What is the only human disease eradicated to date and when was eradication declared?
3. Name the three levels of prevention and give one example strategy for each.
4. Name the six links of the chain of infection in order.
5. What is the fundamental principle of communicable disease control based on the chain of infection?

5.2 Control of Communicable Diseases

5.2.1 Control measures directed at the agent and reservoir

Control measures targeting the **reservoir** aim to reduce or eliminate the population of infected hosts or environmental sources from which the agent can spread. For diseases with a **human reservoir**, measures include case detection and treatment (reducing the period of infectiousness and onward transmission, as in tuberculosis directly observed treatment), and isolation or quarantine of infectious individuals during outbreaks (separating known cases or exposed contacts from the susceptible population for the duration of the communicable period). For diseases with an **animal reservoir (zoonoses)**, measures include animal vaccination (such as rabies vaccination of dogs), animal treatment, or culling of infected animal populations where appropriate.

For diseases with an **environmental reservoir**, measures include decontamination of contaminated water, soil, or surfaces, and modification of environmental conditions that support pathogen survival or vector breeding. **Carrier identification and management** is a specific reservoir-control measure for diseases with asymptomatic carrier states (such as typhoid, where chronic carriers can transmit the disease without showing symptoms themselves); identifying and managing carriers, sometimes including restriction from food handling occupations, interrupts an otherwise hidden source of ongoing transmission. In Nigeria, the Lassa fever control strategy directed at the rodent reservoir includes community-based rodent control and food storage practices that reduce human contact with the Mastomys rat reservoir species.

Fill in the blank: _____ identification and management is a specific reservoir-control measure for diseases with asymptomatic carrier states, such as typhoid, where individuals can transmit disease without showing symptoms themselves.

5.2.2 Control measures directed at transmission

Control measures targeting **transmission** interrupt the pathway by which the agent moves from the reservoir to a new susceptible host, and the specific measures depend heavily on the predominant mode of transmission for the disease in question. For **vector-borne diseases**

(malaria, dengue, yellow fever), measures include the environmental, chemical, biological, and personal protection vector control methods examined in earlier environmental health coursework, such as insecticide-treated bed nets and indoor residual spraying. For **faecal-oral diseases** (cholera, typhoid, hepatitis A), measures include safe water supply, sanitation, food hygiene, and handwashing, interrupting the contamination pathway from infected faeces to a new susceptible host via water or food.

For **airborne and droplet diseases** (tuberculosis, measles, influenza), measures include adequate ventilation, respiratory hygiene (covering coughs and sneezes), use of masks in high-risk settings, and isolation of infectious cases to reduce the density of susceptible contacts within transmission range. For **direct and indirect contact diseases** (including many skin and sexually transmitted infections), measures include barrier methods (condoms for sexually transmitted infections), avoiding shared personal items, and standard infection prevention precautions in healthcare settings, including hand hygiene and personal protective equipment. Selecting the correct transmission-control measure requires accurate understanding of the disease predominant transmission route, underscoring why the descriptive and analytical methods of earlier Series, used to characterise transmission patterns during outbreak investigation, directly inform appropriate control strategy selection.

Fill in the blank: For airborne and droplet diseases such as tuberculosis and measles, control measures include adequate _____ , respiratory hygiene, and isolation of infectious cases to reduce the density of susceptible contacts within transmission range.

5.2.3 Control measures directed at the host

Control measures targeting the **susceptible host** aim to reduce the proportion of the population capable of becoming infected, primarily through **immunisation**, the single most powerful and cost-effective communicable disease control intervention available. Immunisation works at both the individual level (protecting the vaccinated person) and the population level through **herd immunity** (when a sufficiently high proportion of the population is immune, the probability of an infected person encountering a susceptible contact falls so low that sustained transmission cannot occur, indirectly protecting even unvaccinated individuals). The **herd immunity**

threshold varies by disease, depending on its transmissibility; highly transmissible diseases such as measles require very high vaccination coverage (typically above 95%) to achieve herd immunity.

Nigeria **National Programme on Immunisation (NPI)** delivers the routine immunisation schedule recommended by the WHO Expanded Programme on Immunisation, covering diseases including tuberculosis (BCG), polio, diphtheria, pertussis, tetanus, hepatitis B, Haemophilus influenzae type b, pneumococcal disease, rotavirus, measles, and yellow fever. Persistent challenges to achieving adequate immunisation coverage in Nigeria include vaccine hesitancy (sometimes rooted in historical mistrust, religious concerns, or misinformation), cold chain logistics in remote areas, and conflict-related access restrictions in some northern states. Other host-directed control measures include **chemoprophylaxis** (preventive medication, such as malaria chemoprevention for high-risk groups) and **improving host resistance** more broadly through good nutrition, which strengthens general immune function and reduces susceptibility to infection.

Fill in the blank: _____ immunity occurs when a sufficiently high proportion of a population is immune that sustained transmission of an infectious disease cannot occur, indirectly protecting even unvaccinated individuals.

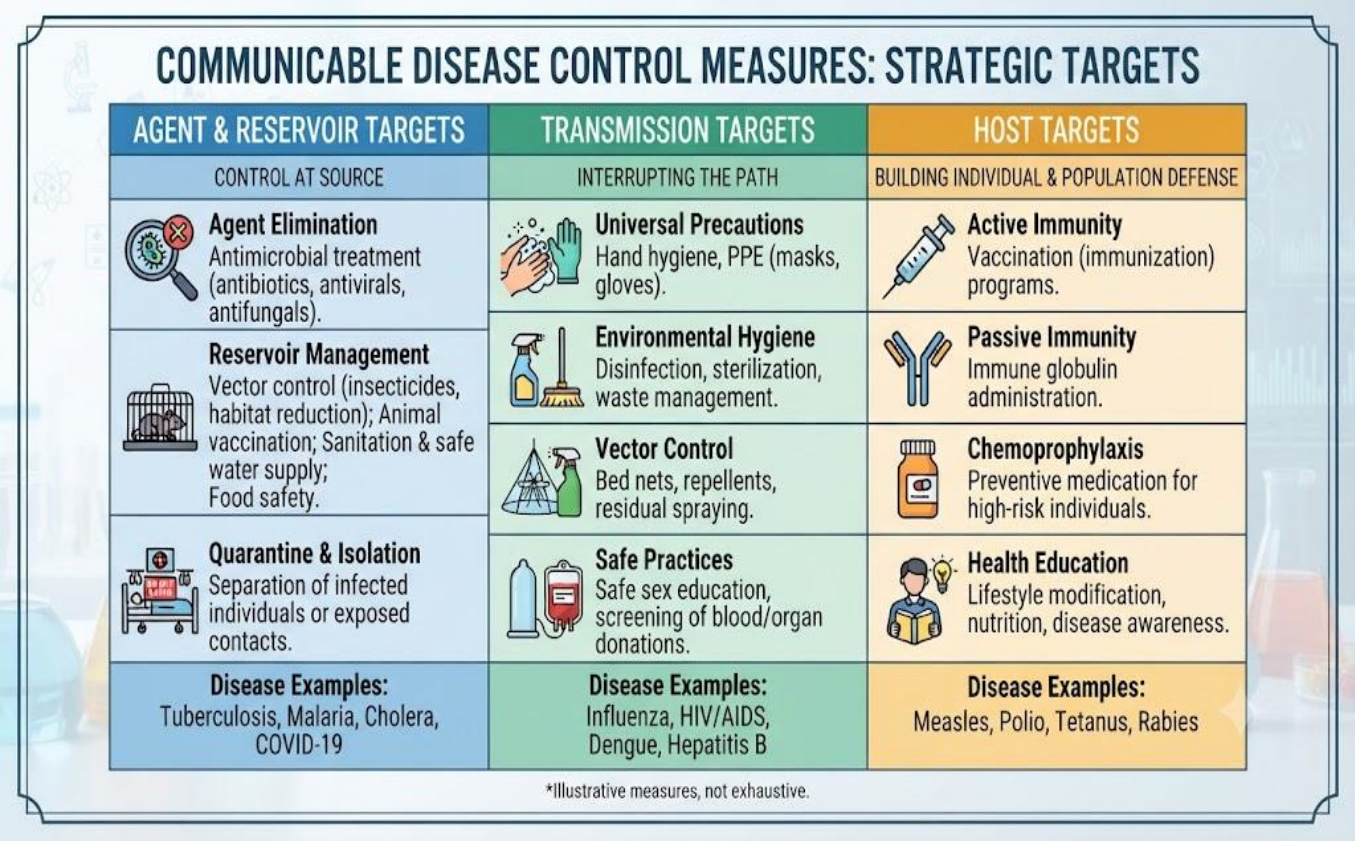


Figure 5.2: Communicable disease control measures by chain of infection target

Pilot questions 5.2

1. Name two reservoir-directed control measures and give a disease example for each.
2. What is a carrier and why does carrier management matter for disease control?
3. Name the transmission-directed control measures appropriate for a faecal-oral disease.
4. Define herd immunity and explain why highly transmissible diseases require higher vaccination coverage to achieve it.
5. Name two challenges to achieving adequate immunisation coverage in Nigeria.

5.3 Control of Non-Communicable Diseases

5.3.1 The rising burden of non-communicable disease in Nigeria

Non-communicable diseases (NCDs), principally cardiovascular disease, cancer, chronic respiratory disease, and diabetes, share common modifiable risk factors and a chronic, typically

slowly progressive course, distinguishing them fundamentally from communicable diseases in both their causation and their control strategy. Nigeria, like much of sub-Saharan Africa, is experiencing a rapid rise in NCD burden, driven by the epidemiological transition introduced in earlier Series: as infectious disease mortality has declined (though not disappeared) and life expectancy has increased, the cumulative lifetime exposure to NCD risk factors has grown, while urbanisation and economic development have simultaneously increased exposure to those risk factors themselves.

Hypertension prevalence among Nigerian adults is estimated at approximately 30%, with the majority undiagnosed or inadequately controlled. Diabetes prevalence is rising, driven by increasing obesity, urbanisation, and dietary transition toward processed, energy-dense foods. Nigeria now faces a **double burden of disease**: continuing high infectious disease mortality (malaria, tuberculosis, HIV, diarrhoeal disease) alongside a rapidly growing NCD burden, placing simultaneous demands on a health system that must develop both communicable disease control infrastructure and chronic disease management capacity, a far more complex undertaking than addressing either burden in isolation.

Fill in the blank: Hypertension prevalence among Nigerian adults is estimated at approximately _____ % , with the majority undiagnosed or inadequately controlled, reflecting weak primary care screening and chronic disease management capacity.

5.3.2 Population-wide and high-risk approaches to NCD prevention

Geoffrey Rose influential framework distinguishes two complementary strategies for NCD prevention. The **population-wide (population-based) approach** aims to shift the entire distribution of a risk factor in the population toward lower risk, through policies and environmental changes that affect everyone (such as taxation of sugar-sweetened beverages, salt content regulation in processed foods, tobacco control legislation, and urban planning that promotes physical activity). Rose key insight, often called the **prevention paradox**, is that a small reduction in risk applied across the entire population can prevent more cases of disease than an intensive intervention applied only to those already at highest individual risk, because the

majority of cases of common diseases arise from the large number of people at moderate risk, not the small number at very high risk.

The **high-risk approach** identifies individuals at elevated risk (through screening, as covered in Series 4) and provides them with intensive, targeted intervention (such as antihypertensive medication for individuals with confirmed hypertension, or statin therapy for individuals with elevated cardiovascular risk scores). The high-risk approach offers a more favourable benefit-to-cost ratio for the individuals targeted and is more readily accepted by both clinicians and patients, since it aligns with conventional clinical practice. The two approaches are complementary rather than competing: an effective national NCD strategy combines population-wide policy measures with targeted high-risk clinical intervention, as reflected in Nigeria National Multi-Sectoral Action Plan for the prevention and control of NCDs.

Fill in the blank: The prevention paradox describes Rose key insight that a small reduction in risk applied across the entire population can prevent _____ cases of disease than an intensive intervention applied only to those at highest individual risk.

5.3.3 Risk factor control and the WHO Best Buys

The WHO has identified a defined set of **"Best Buy" interventions** for NCD prevention and control: cost-effective, feasible, and high-impact interventions appropriate even for resource-constrained health systems. These include **tobacco control** (taxation, smoke-free public places, advertising bans, graphic warning labels); **alcohol control** (taxation, restricted availability, marketing restrictions); **salt reduction** (reformulation of processed foods, public awareness campaigns); **physical activity promotion** (public communication campaigns, supportive urban environments); and **clinical interventions** such as drug therapy and counselling for individuals at high cardiovascular risk, and cervical cancer screening (linking to the screening principles of Series 4).

Nigeria implementation of these Best Buy interventions remains partial: tobacco control legislation exists through the National Tobacco Control Act 2015, but enforcement and taxation levels remain below WHO-recommended thresholds; salt reduction and food reformulation policy is underdeveloped; and clinical management of hypertension and diabetes within the

primary healthcare system is constrained by medication availability, workforce training, and weak chronic disease registers that would enable systematic follow-up. Strengthening NCD risk factor control in Nigeria requires the same combination of policy commitment, intersectoral collaboration (engaging trade, finance, and urban planning sectors alongside health), and health system capacity-building that has been emphasised throughout this Series for communicable disease control, reinforcing that the underlying principles of effective disease control transcend the communicable/non-communicable distinction even as specific measures differ.

Fill in the blank: The WHO "Best Buy" interventions for NCD prevention include tobacco control, alcohol control, salt reduction, physical activity promotion, and clinical interventions such as drug therapy for individuals at high _____ risk.

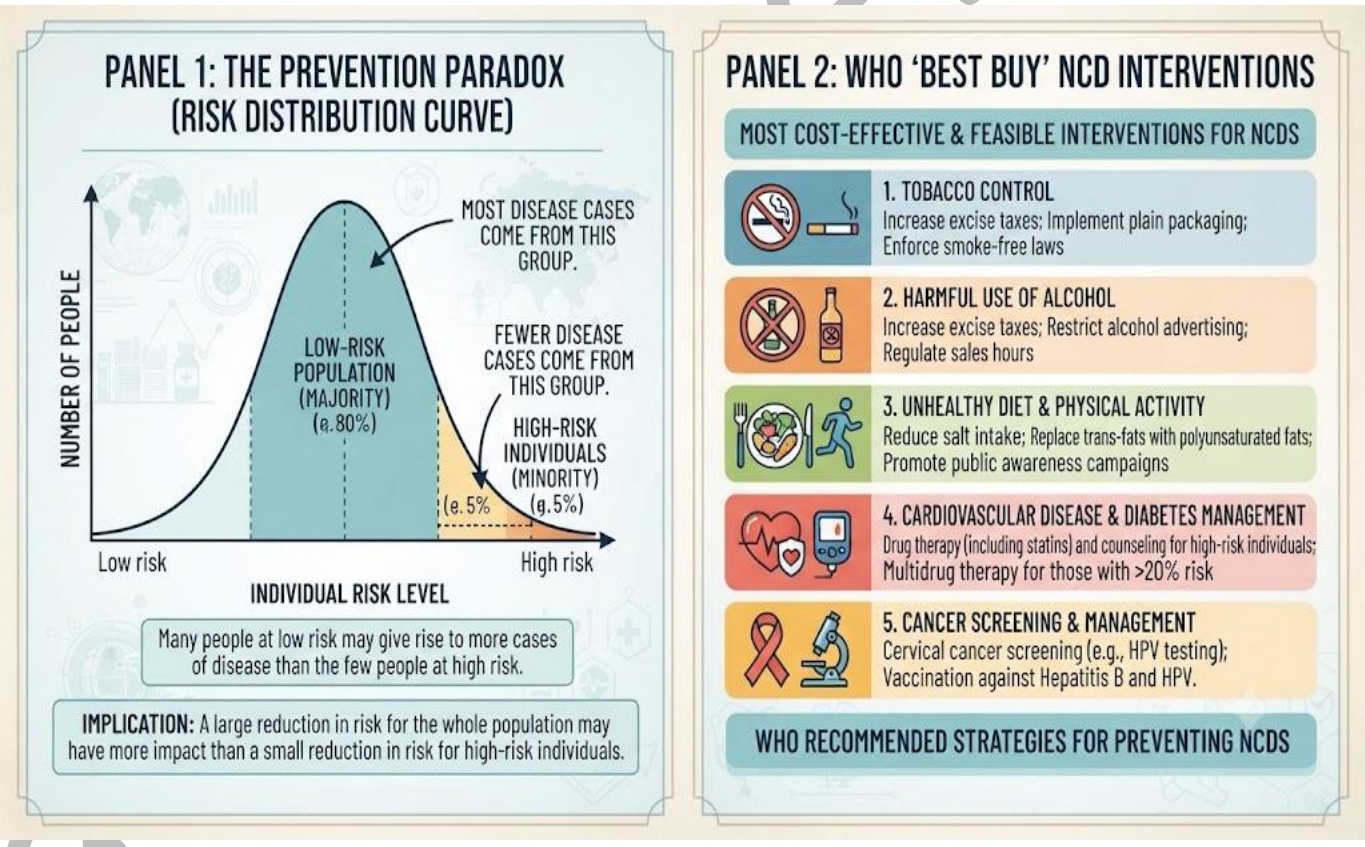


Figure 5.3: Population-wide versus high-risk NCD prevention and the WHO Best Buys

Pilot questions 5.3

1. Why is Nigeria described as facing a double burden of disease?

2. Distinguish between the population-wide approach and the high-risk approach to NCD prevention.
3. Explain the prevention paradox.
4. Name three WHO Best Buy interventions for NCD control.
5. Name two challenges to implementing NCD risk factor control policies in Nigeria.

5.4 Integrated Disease Control in Nigeria

5.4.1 National disease control programmes

Nigeria operates a range of vertical (disease-specific) national control programmes, each applying the principles examined throughout this Series. The **National Malaria Elimination Programme** applies vector-, host-, and case-management-directed control measures toward the long-term goal of malaria elimination. The **National Tuberculosis and Leprosy Control Programme** applies directly observed treatment (reducing the human reservoir and infectious period) alongside contact tracing and BCG immunisation. The **National AIDS and STI Control Programme** combines prevention (condom promotion, pre-exposure prophylaxis), testing (a screening application), and treatment (antiretroviral therapy, which both treats the individual and reduces onward transmission, an approach known as treatment as prevention).

The **National Programme on Immunisation** delivers routine and supplementary immunisation activities targeting vaccine-preventable diseases. Alongside these communicable disease programmes, the **National Multi-Sectoral Action Plan for NCDs** coordinates the population-wide and high-risk strategies examined in Part 5.3. Each of these programmes depends fundamentally on the surveillance, descriptive, and analytical epidemiological methods examined throughout this course: programme targets are set based on baseline disease burden data, progress is monitored through routine surveillance indicators, and programme strategy is periodically revised based on evaluation findings, exemplifying epidemiology function as the evidence engine driving the entire disease control enterprise.

Fill in the blank: The National AIDS and STI Control Programme combines prevention, testing, and treatment with antiretroviral therapy, an approach known as treatment as _____ , since effective treatment also reduces onward transmission to others.

5.4.2 Health system strengthening for disease control

Effective disease control, whether of communicable or non-communicable disease, ultimately depends on the underlying capacity of the health system within which control programmes operate. The WHO health system building blocks framework identifies six interdependent components: **service delivery** (functioning facilities providing the interventions described throughout this Series), **health workforce** (sufficient, appropriately trained personnel, including the environmental health officers, epidemiologists, and clinical staff discussed across this course), **health information systems** (the surveillance and data systems, such as IDSR and DHIS2, that generate the descriptive epidemiological evidence underlying control programme design and monitoring), **access to essential medicines and technologies** (including vaccines, diagnostics, and treatments), **financing** (sustainable funding mechanisms), and **leadership and governance** (policy direction and accountability).

A disease control programme that is technically well-designed, applying the correct epidemiological principles examined throughout this course, will nonetheless underperform if these underlying health system functions are weak: a malaria control programme cannot achieve its targets if bed nets are not reliably distributed (service delivery weakness), if there are insufficient community health workers to conduct distribution and education (workforce weakness), if surveillance data is incomplete (information system weakness), or if funding for commodities is interrupted (financing weakness). This is why effective epidemiological practice in Nigeria, and in any country, must be understood not as an isolated technical exercise but as one component embedded within, and dependent upon, the functioning of the broader health system.

Fill in the blank: The WHO health system building blocks framework identifies six interdependent components: service delivery, health workforce, health information systems, access to essential medicines, financing, and leadership and _____.

5.4.3 Synthesis: epidemiology as the foundation of disease control

This course has traced a coherent arc from the foundational definition and historical development of epidemiology, through the descriptive characterisation of disease by person, place, and time, the analytical methods of cohort and case-control studies and the assessment of bias and confounding, the practical application of epidemiological method to outbreak investigation and screening, and finally to the control strategies, communicable and non-communicable, that epidemiology ultimately exists to inform. At every stage, the same underlying logic has recurred: disease patterns must be accurately described before they can be explained, explanations must be rigorously tested before they are accepted as causal, and only validated causal understanding can reliably guide effective control action.

Nigeria epidemiological challenges, a persistent communicable disease burden alongside a rapidly rising non-communicable disease burden, weak vital registration and surveillance data completeness, and health system capacity constraints across workforce, financing, and infrastructure, are not reasons to abandon epidemiological rigour but precisely the reasons it is most needed. Limited resources demand that interventions be targeted to where the evidence indicates they will have the greatest impact, a determination only epidemiological analysis can reliably provide. As you proceed into further study or practice in public health, the methods established in this course, measuring disease frequency, comparing groups, assessing causation, evaluating interventions, will remain the essential foundation of effective, evidence-based health practice.

Fill in the blank: Disease patterns must be accurately described before they can be explained, explanations must be rigorously _____ before they are accepted as causal, and only validated causal understanding can reliably guide effective control action.

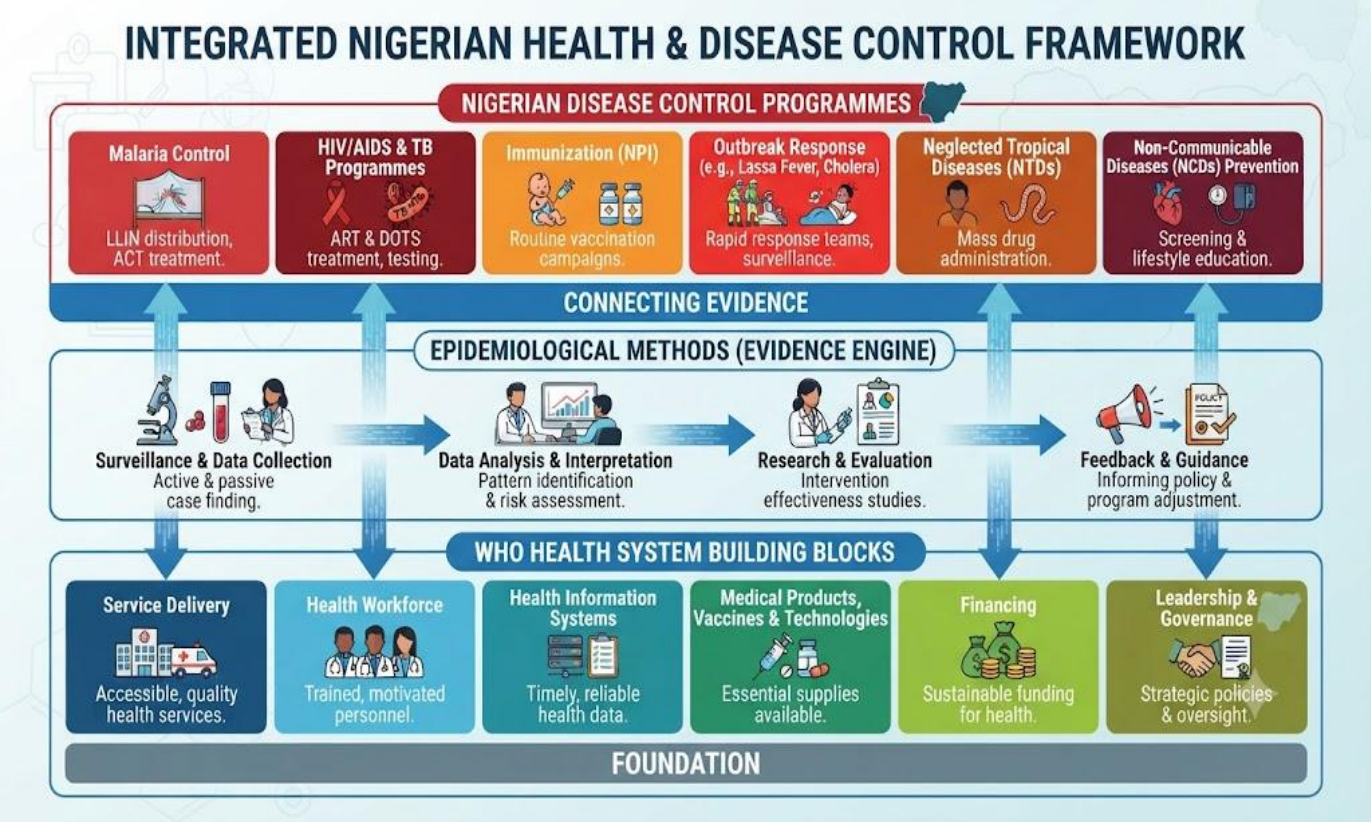


Figure 5.4: Integrated disease control in Nigeria: programmes, health system, and the epidemiological foundation

Pilot questions 5.4

1. Name three national disease control programmes operating in Nigeria and the control strategy each applies.
2. What does "treatment as prevention" mean in the context of HIV control?
3. Name the six WHO health system building blocks.
4. Why can a technically well-designed disease control programme still underperform?
5. Summarise, in your own words, why epidemiology is described as the foundation of disease control.

Series Summary

This final Series established the principles of disease control as the practical culmination of the epidemiological methods examined throughout the course. Control, elimination, and eradication were distinguished as points along a spectrum of ambition, and the chain of infection was introduced as the organising model for communicable disease control, structuring measures around the agent and reservoir, transmission, and host, each illustrated with Nigerian examples spanning malaria, tuberculosis, Lassa fever, and vaccine-preventable disease.

Non-communicable disease control was examined through Nigeria rising NCD burden and the double burden of disease, the complementary population-wide and high-risk prevention approaches and the prevention paradox, and the WHO Best Buy interventions for risk factor control. The Series concluded by synthesising communicable and non-communicable disease control within Nigeria national programme landscape and the WHO health system building blocks framework, establishing that effective disease control depends on both correct epidemiological method and adequate underlying health system capacity, and that epidemiology, as practised across all five Series of this course, remains the essential evidence foundation of public health action (SLOs 5.1 to 5.7).

Glossary of Terms

- **Chain of infection:** a model describing the sequence of links (agent, reservoir, portal of exit, mode of transmission, portal of entry, susceptible host) required for infectious disease transmission.
- **Disease control:** ongoing operations aimed at reducing disease incidence, prevalence, morbidity, or mortality to a locally acceptable level, requiring continued intervention to maintain reduction.
- **Double burden of disease:** the simultaneous presence of high communicable disease mortality and a rapidly rising non-communicable disease burden in a population.

- **Elimination:** the reduction to zero of disease incidence in a defined geographic area, requiring continued measures to prevent re-establishment of transmission.
- **Eradication:** the permanent reduction to zero of worldwide disease incidence, after which intervention measures are no longer needed.
- **Health system building blocks:** the WHO framework identifying six interdependent health system components: service delivery, workforce, information systems, medicines and technologies, financing, and governance.
- **Herd immunity:** population-level protection occurring when a sufficiently high proportion of immune individuals prevents sustained disease transmission, indirectly protecting the unvaccinated.
- **High-risk approach:** an NCD prevention strategy that identifies individuals at elevated risk through screening and provides targeted, intensive intervention.
- **Population-wide approach:** an NCD prevention strategy that shifts the entire population risk factor distribution toward lower risk through broad policy and environmental change.
- **Prevention paradox:** Geoffrey Rose observation that a small risk reduction applied across an entire population can prevent more disease cases than intensive intervention targeted only at high-risk individuals.

Concept Check Questions [Series 5]

Objective questions

1. _____ refers to the permanent reduction to zero of the worldwide incidence of infection caused by a specific agent. (Linked to SLO 5.1)
2. The chain of infection comprises six links: agent, reservoir, portal of exit, mode of transmission, portal of entry, and _____. (Linked to SLO 5.2)
3. _____ immunity occurs when a sufficiently high proportion of a population is immune that sustained disease transmission cannot occur. (Linked to SLO 5.3)
4. Hypertension prevalence among Nigerian adults is estimated at approximately _____ %. (Linked to SLO 5.4)
5. The prevention _____ describes how a small risk reduction applied across an entire population can prevent more disease cases than intensive high-risk targeted intervention. (Linked to SLO 5.5)
6. The WHO health system building blocks framework includes service delivery, workforce, information systems, medicines and technologies, financing, and leadership and _____. (Linked to SLO 5.7)

Short-answer questions

7. Distinguish between disease control, elimination, and eradication, giving one example of each. (Linked to SLO 5.1)
8. Explain the chain of infection and describe one control measure targeting each of the agent/reservoir, transmission, and host. (Linked to SLOs 5.2–5.3)
9. Distinguish between the population-wide and high-risk approaches to NCD prevention and explain why they are complementary. (Linked to SLO 5.5)

Long-answer questions

10. Discuss the principles and measures of communicable disease control in Nigeria, using the chain of infection as an organising framework. (Linked to SLOs 5.2–5.3)

11. Evaluate the rising burden of non-communicable disease in Nigeria and the strategies available for its control. (Linked to SLOs 5.4–5.6)
12. Synthesise the role of epidemiology in disease control in Nigeria, integrating national programmes and health system strengthening. (Linked to SLO 5.7)

Answers to Concept Check Questions [Series 5]

Objective questions

6. Eradication.
7. Susceptible host.
8. Herd.
9. 30.
10. Paradox.
11. Governance.

Short-answer questions

12. Control: ongoing reduction of disease burden requiring continued intervention; example, malaria control in Nigeria. Elimination: zero incidence in a defined area requiring continued measures to prevent resurgence; example, Nigeria wild poliovirus elimination (2020). Eradication: permanent zero worldwide incidence requiring no further intervention; example, smallpox (1980).
13. Chain of infection: agent, reservoir, portal of exit, mode of transmission, portal of entry, susceptible host; breaking any link prevents transmission. Agent/reservoir measure: case detection and treatment (e.g. TB directly observed treatment). Transmission measure: vector control or safe water provision. Host measure: immunisation.
14. Population-wide approach shifts the entire population risk distribution toward lower risk through broad policy (e.g. tobacco taxation). High-risk approach targets individuals identified through screening with intensive intervention (e.g. antihypertensive medication). They are complementary because the population approach prevents the

larger number of cases arising from moderate risk in the whole population, while the high-risk approach offers the most favourable benefit-to-cost ratio for those individuals already at greatest danger.

Long-answer questions

15. **Basic response:** Chain of infection: agent, reservoir, portal of exit, transmission, portal of entry, susceptible host. Reservoir measures: case treatment (TB DOTS), carrier management (typhoid), animal vaccination (rabies), rodent control (Lassa fever). Transmission measures: vector control (malaria bed nets, IRS), water/sanitation/hygiene (cholera, typhoid), respiratory hygiene and isolation (TB, measles), barrier methods (STIs). Host measures: immunisation (NPI routine schedule), chemoprophylaxis (malaria chemoprevention), nutrition (general immune resistance).

Value-added response: The chain of infection value lies in revealing that disease control is never limited to a single strategy: for any communicable disease, multiple intervention points exist simultaneously, and effective national programmes deliberately combine measures across the reservoir, transmission, and host targets rather than relying on any single approach. This redundancy provides resilience: if vaccination coverage falls short in a given area, vector control and case management can still substantially limit transmission, as demonstrated by Nigeria multi-pronged National Malaria Elimination Programme.

16. **Basic response:** Nigeria NCD burden: hypertension approximately 30% of adults, rising diabetes prevalence, driven by epidemiological transition, urbanisation, and dietary change, producing a double burden alongside continuing infectious disease mortality. Population-wide strategies: tobacco and alcohol taxation, salt reduction policy, physical activity-supportive urban planning. High-risk strategies: screening (Series 4) followed by targeted clinical management (antihypertensive medication, statins). WHO Best Buys: tobacco control, alcohol control, salt reduction, physical activity promotion, clinical risk management.

Value-added response: Nigeria NCD response illustrates the prevention paradox in practice: a modest national salt reduction policy affecting all processed food, while seemingly less

dramatic than a hypertension clinic, would likely prevent more cardiovascular events nationally than expanding clinical hypertension treatment alone, because most cardiovascular events arise in the large population at moderate risk rather than the smaller population already flagged as high-risk. Effective NCD policy therefore requires political commitment to population-wide measures that often face resistance from affected industries, not only investment in clinical services.

17. **Basic response:** National programmes: NMEP (malaria), NTBLCP (tuberculosis), NASCP (HIV, including treatment as prevention), NPI (immunisation), National Multi-Sectoral NCD Action Plan. Each depends on epidemiological surveillance and analysis for target-setting and evaluation. Health system building blocks: service delivery, workforce, information systems, medicines/technologies, financing, governance, all required for programme success regardless of design quality.

Value-added response: The course overall arc, from defining epidemiology through descriptive and analytical methods to outbreak investigation, screening, and finally control, demonstrates that epidemiology is not a separate academic discipline sitting apart from disease control practice but its operational engine at every stage: identifying where disease burden is concentrated, testing which interventions work, detecting when control is failing, and measuring whether elimination or eradication targets are being achieved. A Nigerian public health practitioner equipped with these methods is equipped to direct scarce resources toward the interventions most likely to save lives, the ultimate purpose for which epidemiology exists.

Answers to Pilot Questions [Series 5]

Part 5.1

11. Control is ongoing reduction of disease burden to an acceptable level, requiring continued intervention. Elimination is reduction to zero incidence in a defined area,

requiring continued measures to prevent resurgence. Eradication is permanent reduction to zero worldwide incidence, after which no further intervention is needed.

12. Smallpox, declared eradicated in 1980.
13. Primary prevention (e.g. immunisation), secondary prevention (e.g. screening and early treatment), tertiary prevention (e.g. rehabilitation).
14. Agent, reservoir, portal of exit, mode of transmission, portal of entry, susceptible host.
15. Breaking any single link in the chain is sufficient to prevent transmission, providing multiple potential points of intervention for any given disease.

Part 5.2

1. Any two of: case detection and treatment (tuberculosis), carrier identification and management (typhoid), animal vaccination (rabies), environmental decontamination.
2. A carrier is an individual who harbours and can transmit an infectious agent without showing symptoms. Carrier management matters because it interrupts an otherwise hidden source of ongoing transmission that would not be detected through symptomatic case finding alone.
3. Safe water supply, sanitation, food hygiene, and handwashing.
4. Herd immunity occurs when a sufficiently high proportion of the population is immune that sustained transmission cannot occur. Highly transmissible diseases require higher vaccination coverage because more potential transmission chains must be interrupted to prevent sustained spread, given their higher basic reproduction number.
5. Any two of: vaccine hesitancy, cold chain logistics in remote areas, conflict-related access restrictions in some northern states.

Part 5.3

6. Because Nigeria experiences both continuing high infectious disease mortality (malaria, tuberculosis, HIV, diarrhoeal disease) and a rapidly rising non-communicable disease burden simultaneously, placing dual demands on the health system.
7. The population-wide approach shifts the entire population risk factor distribution toward lower risk through broad policy and environmental change affecting everyone. The high-risk approach identifies individuals at elevated risk through screening and provides them with intensive, targeted intervention.
8. The prevention paradox is the observation that a small reduction in risk applied across the entire population can prevent more cases of disease than an intensive intervention applied only to those already at highest individual risk, because most cases of common disease arise from the large number of people at moderate risk rather than the small number at very high risk.
9. Any three of: tobacco control, alcohol control, salt reduction, physical activity promotion, clinical risk management interventions.
10. Any two of: enforcement and taxation levels below WHO-recommended thresholds; underdeveloped salt reduction and food reformulation policy; limited medication availability and workforce training for chronic disease management; weak chronic disease registers.

Part 5.4

11. Any three of: National Malaria Elimination Programme (vector, host, and case-management control), National Tuberculosis and Leprosy Control Programme (directly observed treatment, contact tracing, BCG immunisation), National AIDS and STI Control Programme (prevention, testing, treatment as prevention), National Programme on Immunisation (routine and supplementary immunisation).
12. Treatment as prevention means that effective antiretroviral therapy not only treats the individual living with HIV but also substantially reduces the risk of onward transmission to others, meaning treatment itself functions as a transmission control measure.

13. Service delivery, health workforce, health information systems, access to essential medicines and technologies, financing, and leadership and governance.
14. Because disease control depends not only on correct technical design but also on the underlying health system capacity to deliver it; weaknesses in workforce, information systems, supply chains, or financing can undermine even a well-designed programme regardless of its technical correctness.
15. Epidemiology provides the methods, measuring disease frequency, comparing groups, testing causal hypotheses, evaluating interventions, that identify where disease burden is concentrated and which control measures are effective, making it the evidence foundation upon which all disease control decisions and programme evaluations ultimately rest.

References and Attributions [Series 5]

Textual references

1. Gordis, L. (2014). Epidemiology (5th ed.). Elsevier Saunders.
2. Rose, G. (1985). Sick individuals and sick populations. International Journal of Epidemiology, 14(1), 32-38.
3. World Health Organization. (2013). Global action plan for the prevention and control of noncommunicable diseases 2013-2020. WHO Press.
4. National Open University of Nigeria (NOUN). (2023). Introduction to general epidemiology course material. NOUN Press.

Figures, Plates, Tables, and Boxes

1. Figure 5.1: Disease control concepts and the chain of infection Attribution: AI generated using prompt "Generate a two-panel diagram showing the control-elimination-eradication spectrum with examples, and the six-link chain of infection with a malaria control example at each link." Suggested OER search string: "disease control elimination eradication chain of infection malaria control points OER"
2. Figure 5.2: Communicable disease control measures by chain of infection target Attribution: AI generated using prompt "Generate a three-column table of communicable disease control measures organised by agent/reservoir, transmission, and host targets with disease examples." Suggested OER search string: "communicable disease control measures reservoir transmission host immunisation herd immunity Nigeria OER"
3. Figure 5.3: Population-wide versus high-risk NCD prevention and the WHO Best Buys Attribution: AI generated using prompt "Generate a two-panel diagram showing the prevention paradox risk distribution curve and a list of WHO Best Buy NCD interventions." Suggested OER search string: "prevention paradox Rose population approach high-risk approach WHO Best Buys NCD Nigeria OER"
4. Figure 5.4: Integrated disease control in Nigeria: programmes, health system, and the epidemiological foundation Attribution: AI generated using prompt "Generate a layered

diagram showing Nigerian disease control programmes resting on the WHO health system building blocks, with epidemiological methods as the connecting evidence engine." Suggested OER search string: "integrated disease control Nigeria WHO health system building blocks epidemiology national programmes synthesis OER"