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UNIT – I

BIOCHEMICAL LABORATORY

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CLINICAL LABORATORY

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WHAT IS BIOCHEMISTRY ?

A basic science which deals with chemical nature and chemical behaviour of living matter and with the reactions and processes they undergo. Biochemistry involves the study of: Chemical constituents of living matter.

- Chemical changes which occur in the organism during digestion, absorption and excretion.
- Chemical changes which occur during growth and multiplication of the organism.
- Transformation of one form of chemical constituent to the other.
- Energy changes involved in such transformation
- Note:- The term "Biochemistry" was first introduced by German chemist Carl Neuberg in 1903 from Greek word "bios" means "life".

CLINICAL BIOCHEMISTRY

- ❖ It mainly deals with the biochemical aspects that are involved in several conditions.
- ❖ The results of qualitative and quantitative analysis of body fluids assist the clinicians in the diagnosis, treatment and prevention of the disease and drug monitoring, tissue and organ transplantation, forensic investigations and so on.
- ❖ Various biological fluids subjected to chemical tests and assays include blood, plasma, serum, urine, cerebrospinal fluid (CSF), ascetic fluid, pleural fluid, faeces, calculi and tissues.

BIOCHEMICAL LABORATORY

- In the era of modern technology, health care delivery system involves so many different personnel and specialties that the caregiver must have an understanding and working knowledge of other professional endeavors, including the role of diagnostic evaluation.
- Basically, laboratory and diagnostic tests are tools by and of themselves, they are not therapeutic.
- In conjunction with a pertinent history and physical examination, these tests can confirm a diagnosis or provide valuable information about a patient status and response to therapy.
- In addition to these, laboratory findings are essential for epidemiological surveillance and research purposes.

ROLES OF CLINICAL LABORATORY

- The medical laboratory services play a pivotal role in the promotion, curative and preventive aspects of a nation's health delivery system.
- The service gives a scientific foundation by providing accurate information to those with the responsibility for:
- Treating patients and monitoring their response to treatment,
- Monitoring the development and spread of infectious and dangerous pathogens (disease causing organisms)
- Deciding effective control measures against major prevalent disease.

Biochemical laboratory

- A biochemistry laboratory is an area in which a **biochemist** studies the chemical processes within living organisms.
- Biochemical research has expanded to cover topics of signal transduction, transport within cells, and molecular interactions.

- All biochemistry labs will have the basic components of science research labs, such a pH meter, a balance for weighing out chemicals, a variety of buffers and other chemicals, and refrigerators and freezers for storing supplies.
- They will also have a special freezer kept at -94° F (-70° C) for the long-term storage of proteins and tissues.
- Virtually all biochemistry labs will have gel electrophoresis supplies for examining proteins, along with the equipment for running Western blots.

Basic equipments used in Biochemistry Laboratory:-

1. Centrifuge
2. Water bath
3. Hot Air Oven
4. Colorimeter
5. Spectrophotometer
6. Flame photometer
7. Micro pipettes
8. Auto analyzer
9. Refrigerator

Centrifuge:-

- It is a separation technique used in clinical and research laboratories.
- It is based on the principle of centrifugal force.

Types:-

(i) Hand centrifuge
(ii) Motor Driven centrifuge
(iii) Micro – Hematocrit centrifuge

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Role of Biochemical Laboratory:-

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(i) Treating patients and monitoring their response to treatment,

(ii) Monitoring the development and spread of infectious and dangerous pathogens (disease causing organisms)

(iii) Deciding effective control measures against major prevalent disease.

Without reliable laboratory services:

1.) The source of a disease may not be identified correctly.

2.) Patients are less likely to receive the best possible care.

3.) Resistance to essential drugs may develop and continue to spread.

4.) Epidemic disease may not be identified on time and with confidence.

Automation in clinical Biochemistry:-

- Automation means getting work done by machine which can run on their own.
- This is without our continuous monitoring.
- Automation refer to machine with intelligence and adaptability which reduce our workload and need for nonstop supervision.

STEPS INVOLVED IN ANALYSIS PROCESS ARE AS FOLLOWS:-

➜ Identifying the patient
➜ Getting the correct sample
➜ Identifying and proper labelling of the sample
➜ Delivery of sample in proper storage condition and within time
➜ Preparation of sample for test
➜ Sample loading
➜ Analysis
➜ Reporting
➜ Entering in register

BENEFITS OF AUTOMATION

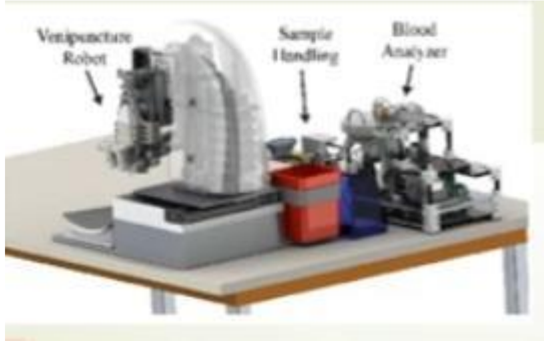
✓ Reduce the workload
✓ Increase turnaround time
✓ Increase total Number of test done in less time
✓ Eliminates repetition and monotony from human life. so, decrease human error, improve accuracy.
✓ Improve reproducibility (repeatability)
✓ Use minimum amount of sample and reagent

STEPS INVOLVED IN AUTOMATED SAMPLE ANALYZERS :-

1. Sample collection
2. Sample identification by labeling and bar coding
3. Sample Delivery
4. Sample preparation

<u>SAMPLE COLLECTION:-</u>

- In automated analysis, at times just a prick of finger is sufficient to collect samples. Example - Glcometer
- Automation in sample collection mainly refer to improved faster, and least discomfort causing techniques of collection.
- Such as : **Robotic system, Vacutainers etc..**



- Blood collected using a vacutainer.Here the phlebotomist need not pull the syringe,blood gets sucked in due to negative pressure filling the vaccum.
- Different types of Vacutainers for serum collection and for plasma collection using different types of anticoagulants.
- The identification is done with the colour of caps used.

SAMPLE IDENTIFICATION BY LABELING AND BAR CODING:-

- Labs generate a unique identify or hospital number for each new patient.
- All sample collected have to bear the name and details of the patient along with this unique identify.
- The same is used while entering the details into auto analyzer software and result is also published with this number and other details.

- Some advanced labs are using computer generated Bar coding technology for labelling samples.
- This Bar coding avoids human errors.
- Bar coding of the patient unique sample identify is attached to his/her wrist.
- Even, when patient is sleeping or unconscious,nurse can read the code for patient identification.

- Bar coding of blood bag in hematology,stores entire detail of type of blood,its components, storage condition,time of storage etc just by bar coding.

SAMPLE DELIVERY :

- Old ones: Human pick up systems which are cheaper.
- Few Advanced labs pneumatic tube systems (use of pressurized gas to move the tubes containing samples)
- Highly advanced laboratories use mobile robots.

- The automated sample processors are of 2 types:-
  (i) Stand alone automated sample processors.
  (ii) Independent automated sample processors.

SAMPLE PREPARATION

:

- These automated sample processors can do the following tasks:-
  Sorting of samples.
  Removing caps
  Separating samples
  Bar coding etc..

MECHANISATION AND AUTOMATION IN CLINICAL LABBORATORY

Automation in the clinical laboratory

- Introduction
- Automation of the Analytical Process
  - Unit Operations
    - Specimen identification
    - Specimen preparation
    - Specimen delivery
    - Specimen loading and aspiration
    - Specimen processing
    - Sample induction and internal transport
    - Reagent handling and storage
    - Chemical reaction phase
    - Measurement approaches
    - Signal processing, data handling and process control
- **Applications**

Automation
in the clinical laboratory

Definition:

“ The process whereby an analytical instrument performs many tests with only minimal involvement of an analyst”

“ Controlled operation of an apparatus, process, or system by mechanical or electronic devices without human intervention”

Advantages of automation

Automated instruments enables laboratories to

- **Process much larger workloads**
- **Reduce number of staff**
- **Reduction in the variability of results and errors of analysis**
- **Significant improvement in the quality of lab tests**
- **Cost reduction**

Advantages of Automation

- Assist the laboratory technologist in test performance

(1) Processing and transport of specimens

(2) Loading of specimens into automated analyzers

(3) Assessment of the results of the performed tests.

Principle: Automation in the clinical laboratory

- **Automated analyzers generally incorporates mechanized version of basic manual laboratory techniques and procedures**
- Modern instrumentation is packaged in a wide variety of configurations.
- **Common configuration** is the **Random-Access Analyzer**.

Random-Access Analysis

Analyses are performed on a collection of specimens **sequentially**,

with each specimen analyzed for a different selection of tests.

- This approach permits measurement of a variable number and variety of analytes in each specimen

Random-access analysis

- Profiles or groups of tests are defined for a specimen at the time the tests to be performed are entered into the analyzer

(1) A keyboard

(2) by instruction from a laboratory information system

(3) Conjunction with bar coding on the specimen tube

(4) by operator selection of appropriate reagent packs

Unit Operations

(11) Steps required to complete an analysis are referred to collectively as **unit operations**

- Specimen identification
- Specimen preparation
- Specimen delivery
- Specimen loading and aspiration
- Specimen processing
- Sample introduction and internal transport
- Reagent handling and storage
- Reagent delivery
- Chemical reaction phase
- Measurement approaches
- Signal processing, data handling, and process control

1- Specimen Identification

Automatic Identification and Data Collection (AIDC)

- **Electronically detect a unique characteristic** or <u>unique data string associated with a physical object</u>.

Example of identifiers:

(1) **Serial number**
(2) **Part number**
(3) **Colour**
(4) **Manufacturer**
(5) **Patient number**

Automatic Identification and Data Collection

- Bar coding
- Optical character recognition
- Magnetic stripe and magnetic ink character recognition
- Voice identification
- Radiofrequency identification
- Touch screens
- Light pens
- Hand print tablets
- Optical mark readers
- Smart cards

2- Specimen Preparation

Manually Specimen Preparation process results in a delay

Examples :

- ❑ Clotting of blood
- ❑ Centrifugation
- ❑ Transfer of serum to secondary tubes

2- Specimen Preparation

- **Whole blood assay system:** specimen preparation time essentially is eliminated.
- Automated or semi automated ion-selective electrodes: Measure ion activity in whole blood rather than Ion concentration

3- Specimen Delivery

Methods are used to deliver specimens to the lab

1) Courier Service
2) Pneumatic tube systems
3) Electric track vehicles:
4) Mobile robots

4- Specimen Loading and Aspiration

- Automatic analyzer directly analyzed serum/plasma from primary collection tube

- Serum transferred from the specimen tubes to **cups**

CUP features:

- **Permit required volume for testing**
- **Made of inert material**
- **Disposable**
- **Minimize cost**
- **Minimize Evaporation**

4- Specimen Loading and Aspiration

- Specimens may undergo
  - Evaporation
  - Degradation

a) **Thermo-labile Analytes:** Temperatures
b) **Photo labile Analytes** : Photo degradation. E.g.: Bilirubin

- Specimens and calibrators are held at refrigerated loading zone for Thermo-labile Analytes
- Reduced Photo-degradation by
  - **Semi-opaque cups**
  - **smoke- or orange-colored plastic covers**

The loading zone: area in which specimens are held in the instrument before they are analyzed.

5- Specimen Processing

- ❑ Automation of analytical procedures requires removal of

- **Proteins**
- **Other interferants**

- ❑ To automate this separation step, several automated **immunoassay analyzers** use bound **antibodies or proteins** in a solid phase format.

6- Sample Introduction and Internal Transport

- Sample introduction into the analyzer and its subsequent transport within the analyzer

A) Continuous-flow Systems

B) Discrete Processing Systems

7- Reagent Handling and Storage

- **Reagent Handling:**

Labels on reagent containers include information such as

(1) Reagent identification

(2) Volume of the contents or number of tests

(3) Expiration date

(4) Lot number

Storage

- **Plastic or glass** containers used for reagents storage

8- Reagent Delivery

- Liquid reagents are acquired and delivered to mixing and reaction chambers either by
- **Pumps (through tubes)**
- **Positive-displacement syringe devices**

9- Chemical Reaction Phase

- **Sample and reagents react in the chemical reaction phase.**
- Factors are important in this phase

(1) Vessel in which the reaction occurs
(2) Cuvet in which the reaction is monitored
(3) Timing of the reaction(s)
(4) Mixing and transport of reactants
(5) Thermal conditioning of fluids.

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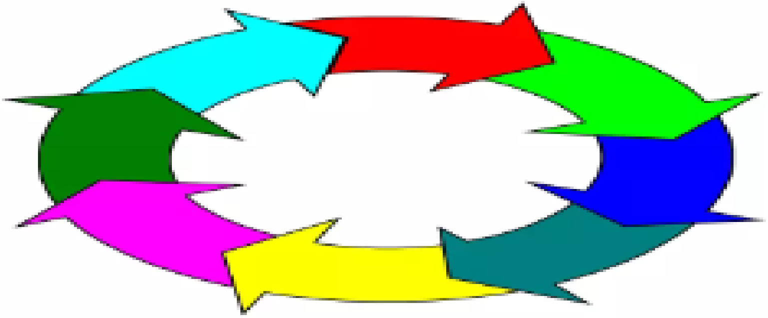
10- Measurement Approaches

- ❑ Photometers
- ❑ Spectrophotometer
- ❑ Fluorometers
- ❑ Luminometers

QUALITY CONTROL IN CLINICAL LABORATORY

Quality ?

- sum-total of all the characteristics of a product/service that has a bearing upon the utilization of the product/service to the entire satisfaction of the consumer



- Conformance to the requirements of users or customers and the satisfaction of their needs and expectations

✓ 1) Acceptable

✓ 2) Accessible

✓ 3) Affordable

✓ 4) Appropriate

Introduction

- The issue of laboratory quality has evolved over more than 4 decades since the 1st recommendation for quality control were published in 1965

- Now, quality control is seen as only one part of a total laboratory control program

- Quality also includes:

  a) Total Quality Management (TQM)→ an activity to **improve pt. care** by having the lab monitor, its work to detect deficiencies & subsequently correct them

QUALITY CONTROL IN CLINICAL LABORATORY

- Quality control is an essential aspect of laboratory operations, ensuring that the laboratory produces accurate and reliable results.
- It involves the implementation of procedures and practices to ensure that the laboratory's work is done in accordance with established standards, guidelines, and protocols.

Objectives of Quality Control in Laboratory:

1. Ensure accuracy and reliability of laboratory results.
2. Prevent errors and contamination.
3. Maintain compliance with regulations and guidelines.
4. Improve efficiency and productivity.
5. Enhance customer satisfaction.

Elements of quality control in laboratory

Standard Operating Procedures (SOPs): Established procedures for laboratory operation including testing, analysis, and reporting.

1. **Calibration and Maintenance**: Regular calibration and maintenance of equipment to ensure accuracy and precision.
2. **Quality Control Samples**: Regularly analyzed samples to ensure the quality of laboratory results.
3. **Internal Audits**: Regular reviews of laboratory operations to identify areas for improvement.
4. **Staff Training**: Ongoing training and education for laboratory staff to ensure they are competent in their roles.
5. **Documentation**: Accurate and complete documentation of laboratory activities, including test results, reports, and records.

6. Quality Assurance Programs: Programs designed to monitor and improve the quality of laboratory results.

- Types of Quality Control in Laboratory:
- In a clinical laboratory, internal and external control are crucial concepts in ensuring the quality and accuracy of test results. Here's a breakdown of both:
- **Internal Control:**
- Internal control refers to the measures taken within the laboratory to monitor and regulate the testing process, ensuring that it operates efficiently and effectively.

1. **Calibration**: Ensuring that instruments and equipment are properly calibrated to ensure accurate measurements.
2. **Quality Control (QC) samples**: Using QC samples to verify the performance of instruments, reagents, and laboratory procedures.
3. **Internal Standardization**: Establishing internal standards for testing procedures, reagents, and equipment to ensure consistency.
4. **Laboratory Information System (LIS) management**: Maintaining accurate and up-to-date records of test results, patient information, and laboratory operations.
5. **Staff training**: Providing ongoing training and education to laboratory staff to ensure they are competent in performing tests and interpreting results.

- **External Control:**
- External control refers to the measures taken by organizations outside the laboratory to verify its performance and accuracy.

1. **Proficiency Testing (PT) programs**: Participating in PT programs that send unknown samples to the laboratory for testing, allowing them to assess their performance against other laboratories.
2. **Regulatory agency inspections**: Inspections by regulatory agencies, such as the College of American Pathologists (CAP) or the Centers for Medicare and Medicaid Services (CMS), to ensure compliance with laboratory regulations and standards.
3. **Accreditation**: Obtaining accreditation from organizations like CAP or the Joint Commission International (JCI) to demonstrate a commitment to quality and patient safety.
4. **External auditing**: Conducting regular audits by external organizations or experts to assess laboratory operations, quality control, and patient safety.
5. **Peer review**: Peer review of test results and laboratory procedures by external experts or peer reviewers to identify areas for improvement.

- By implementing both internal and external control measures, clinical laboratories can:

1. Ensure the accuracy and reliability of test results
2. Identify and correct errors or deficiencies
3. Demonstrate a commitment to quality and patient safety
4. Maintain compliance with regulatory requirements
5. Improve overall laboratory performance and efficiency

In summary, internal control focuses on monitoring and regulating the laboratory's operations, while external control verifies the laboratory's performance through external assessments and evaluations.

ACCURACY AND PRECISION

- Accuracy refers to the closeness of the result obtained by a laboratory test to the true value of the patient's condition. In other words, it is the degree of conformity between the result obtained by a test and the actual value of the parameter being measured.

- Precision, on the other hand, refers to the degree of agreement among multiple measurements of the same parameter. It is a measure of the reproducibility of a test, i.e., how consistent the results are when the test is repeated multiple times under the same conditions.

- **Why are Accuracy and Precision Important in Clinical Laboratory?**

1. **Patient Care**: Accurate and precise test results enable healthcare providers to make informed decisions about patient care, which can lead to improved patient outcomes.
2. **Clinical Decision-Making**: Inaccurate or imprecise test results can lead to incorrect diagnoses, mismanagement of patient care, and potentially serious consequences.
3. **Quality Assurance**: Ensuring accuracy and precision in laboratory testing helps to maintain quality assurance standards, which are essential for maintaining credibility and trust among patients and healthcare providers.
4. **Regulatory Compliance**: Laboratories must adhere to regulatory guidelines, such as those set by CLIA (Clinical Laboratory Improvement Amendments) and ISO 15189, which emphasize the importance of accuracy and precision in laboratory testing.

SELECTION AND OPTIMIZATION OF LABORATORY METHODS. CLINCAL EVALUATION OF LABORATORY METHODS

SELECTION OF LABORATORY METHODS :

- The process of choosing the most suitable laboratory technique or assay to achieve a specific research goal or objective.

- **Specificity**: Choose a method that specifically measures the desired analyte or outcome.
- **Sensitivity**: Select a method with sufficient sensitivity to detect the expected range of values.
- **Accuracy**: Opt for a method with high accuracy to ensure reliable results.
- **Precision**: Choose a method with high precision to minimize variability.
- **Cost-effectiveness**: Consider the cost of reagents, equipment, and personnel time.

OPTIMIZATION OF LABORATORY METHODS

- The process of refining and improving a laboratory technique or assay to achieve the best possible results, including maximizing sensitivity, accuracy, and precision while minimizing errors and variability.

- **Standardization** : The process of establishing a consistent and uniform protocol or procedure for a laboratory method to ensure reproducibility and comparability of results.
- **Calibration**: The process of configuring and fine-tuning laboratory instruments and equipment to ensure accurate and precise measurements.
- **Quality Control:** The process of monitoring and controlling laboratory procedures and results to ensure accuracy, precision, and reliability.

- **Method Validation:** The process of verifying that a laboratory method produces accurate and reliable results for its intended purpose.
- **Troubleshooting**: The process of identifying and resolving problems or issues that arise during laboratory procedures.
- **Refining conditions:** Refine experimental conditions, such as temperature, pH, or reaction time, to optimize results.
- **Sample preparation:** Optimize sample preparation techniques to ensure consistent and representative samples.

CLINICAL EVALUATION OF LABORATORY METHODS:

- The process of assessing the performance and effectiveness of a laboratory test or method in a clinical setting.

- **Diagnostic Accuracy**: How well the test diagnoses the target condition.
- **Clinical Sensitivity:** How well the test detects the target condition in patients with the condition.
- **Clinical Specificity:** How well the test excludes the target condition in patients without the condition.
- **Positive Predictive Value** (PPV): The probability of a positive result indicating the presence of the condition.

- **Negative Predictive Value (NPV)**: The probability of a negative result indicating the absence of the condition.
- **Clinical Utility:** How well the test informs patient care and management decisions.
- **Cost-Effectiveness**: The balance between the test’s benefits and costs.

- Some key steps in clinical evaluation of laboratory methods include:
- **Method Validation:** Verifying the test's performance characteristics.
- **Clinical Trials:** **A**ssessing the test's performance in a clinical setting.
- **Retrospective Studies**: Analyzing existing data to evaluate the test's performance.
- **Prospective Studies**: Collecting data in real-time to evaluate the test's performance.

- **Meta-Analyses**: Combining data from multiple studies to evaluate the test's performance.
- By conducting a thorough clinical evaluation, healthcare professionals can ensure that laboratory methods provide accurate and reliable results, ultimately leading to better patient outcomes.

biochemical analysis in urine and blood , analysis of protein , blood gases.

Biochemical Analysis of Urine and Blood

Purpose of Biochemical Analysis: To diagnose, monitor, and manage various medical conditions by examining the chemical composition of body fluids.

Types of Samples: Blood and urine are commonly used due to their diagnostic value and ease of collection.

Urine Biochemical Analysis

Urine Composition

Basic Components: Water, urea, creatinine, uric acid, electrolytes (sodium, potassium, chloride), and other solutes.

Variation Factors: Hydration status, diet, medications, and physiological conditions.

Urinalysis Techniques

Dipstick Testing: Rapid, semi-quantitative tests using reagent strips. Measures pH, specific gravity, glucose, protein, ketones, bilirubin, and blood.

Microscopic Examination: Identifies cells, crystals, bacteria, and casts.

Chemical Reactions: Enzyme-linked reactions for detecting substances like glucose or protein.

Key Urinary Markers

Glucose: Presence indicates potential diabetes or renal threshold exceedance.

Proteins: Proteinuria can indicate kidney disease or systemic conditions like hypertension.

Ketones: High levels suggest diabetic ketoacidosis or fasting.

Bilirubin: Indicates liver dysfunction or hemolysis.

Blood: Haematuria can signal urinary tract infection, kidney stones, or trauma.

Blood Biochemical Analysis

Blood Composition

Basic Components: Plasma (water, proteins, electrolytes, nutrients, hormones), cells (red blood cells, white blood cells, platelets).

Components of Interest: Electrolytes, enzymes, hormones, proteins, and metabolic by-products.

Blood Test Types

Complete Blood Count (CBC): Assesses red and white blood cells, haemoglobin, haematocrit, and platelets.

Basic Metabolic Panel (BMP): Measures glucose, calcium, electrolytes and kidney function markers.

Comprehensive Metabolic Panel (CMP): Includes BMP plus additional protein levels, liver enzymes (ALT, AST), and bilirubin.

Key Blood Markers

Glucose: Elevated levels suggest diabetes or impaired glucose tolerance.

Electrolytes: Sodium, potassium, and chloride balance is crucial for heart and muscle function.

Proteins: Total protein, albumin, and globulin levels can indicate liver function or nutritional status.

Enzymes: Liver enzymes (ALT, AST) and cardiac markers (troponin, CK-MB) help diagnose liver diseases and myocardial infarction.

Lipid Profile: Includes cholesterol levels (total, LDL, HDL) and triglycerides to assess cardiovascular risk.

Analysis of Plasma Proteins

Overview of Plasma Proteins

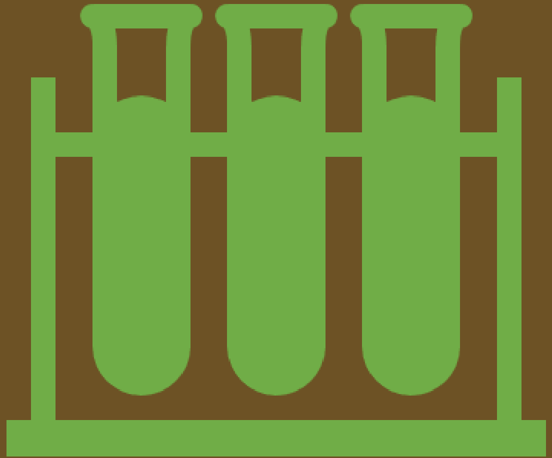
Composition: Plasma proteins are primarily albumin, globulins, and fibrinogen.

Functions: Maintain osmotic pressure, transport substances, and contribute to immune response.

Plasma Protein Electrophoresis

Technique: Separates proteins based on their charge and size using an electric field.

Results Interpretation: Distinct bands representing albumin, alpha-1, alpha-2, beta, and gamma globulins.

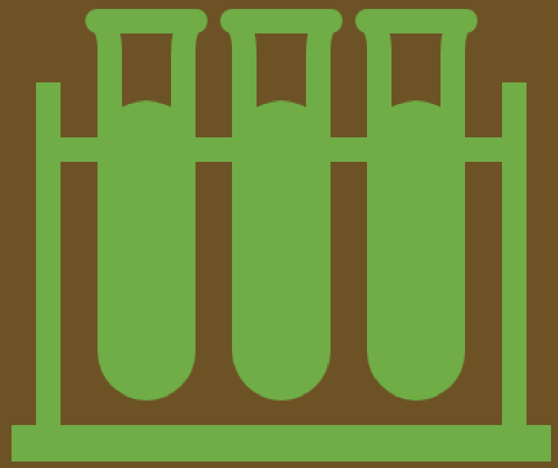


Acute Phase Response

Inflammatory Response: During inflammation, the liver increases production of acute-phase proteins.

Key Acute-Phase Proteins: C-reactive protein (CRP), fibrinogen, and alpha-1 antitrypsin.

Electrophoresis Patterns: Increased alpha-1 and alpha-2 globulins; rise in fibrinogen.



paraproteins

Overview

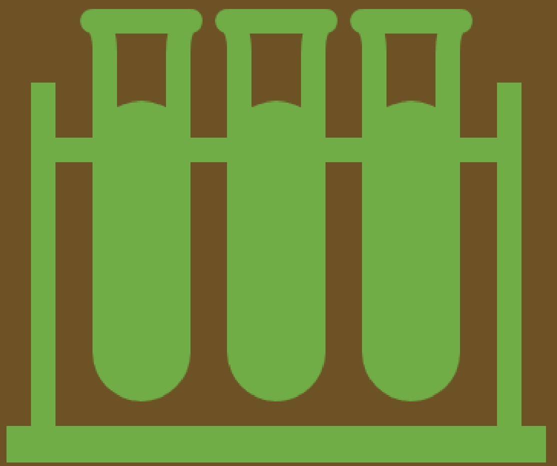
Paraproteins: Abnormal monoclonal proteins produced by clonal proliferation of plasma cells.

Common Disorders: Multiple myeloma, Waldenström macroglobulinemia, and monoclonal gammopathy of undetermined significance (MGUS).

Types of Paraproteins

Monoclonal Gammopathy: Presence of a single clone of plasma cells producing a monoclonal protein.

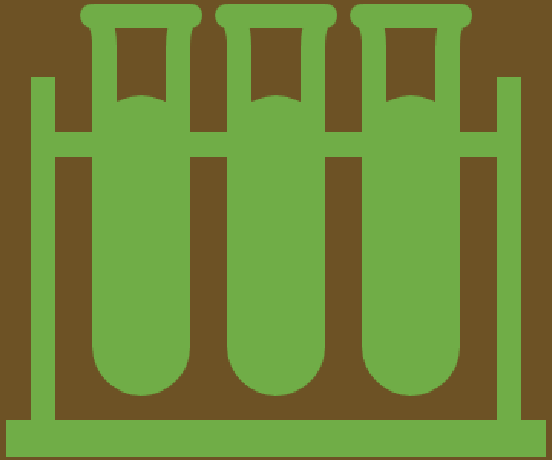
Types: IgG, IgA, IgM, and their light chains (kappa and lambda).



Detection Methods

Serum Protein Electrophoresis (SPEP): Identifies monoclonal bands in the gamma region.

Immunofixation Electrophoresis (IFE): Characterizes the type of paraprotein by identifying specific light and heavy chains.



Blood Gases

Overview

Components: Measures pH, partial pressures of oxygen (pO2) and carbon dioxide (pCO2), bicarbonate (HCO3-), and oxygen saturation.

Significance: Provides information on respiratory and metabolic function.

Blood Gas Analysis Techniques

Arterial Blood Gas (ABG): Standard method for assessing gas exchange and acid-base balance.

Capillary Blood Gas: Used in neonates and for less invasive monitoring.

Acid-Base Balance:

Metabolic Acidosis/Alkalosis: Changes in HCO3-.

Respiratory Acidosis/Alkalosis: Changes in pCO2.

Oxygenation:

pO2: Indicates the effectiveness of oxygenation.

Oxygen Saturation: Reflects the percentage of haemoglobin bound with oxygen.

Normal Ranges and Their Significance

pH: 7.35-7.45; reflects acid-base status.

pCO_2: 35-45 mmHg; indicates respiratory function.

HCO_3^-: 22-28 mmol/L; reflects metabolic component of acid-base balance.

pO_2: 75-100 mmHg; measures oxygenation efficiency.

Oxygen Saturation: 94-100%; percentage of hemoglobin bound with oxygen.

ELECTROLYTES

Electrolytes and acid – base balance. Regulation of electrolyte content of body fluids and maintenance of pH reabsorption of electrolytes. Acidosis & Alkaloids and their determination in clinical laboratory

ELECTROLYTES

- Electrolytes play a crucial role in maintaining acid-base balance in the body. Here's a brief overview:

What are electrolytes?

- Electrolytes are electrically charged minerals that help regulate various bodily functions, including:
- 1. Fluid balance2. pH balance (acid-base balance)3. Nerve function4. Muscle function*

Common electrolytes:*

- 1. Sodium2. Potassium3. Calcium4. Magnesium5. Chloride6. Phosphate7. Bicarbonate*

Acid-Base Balance:

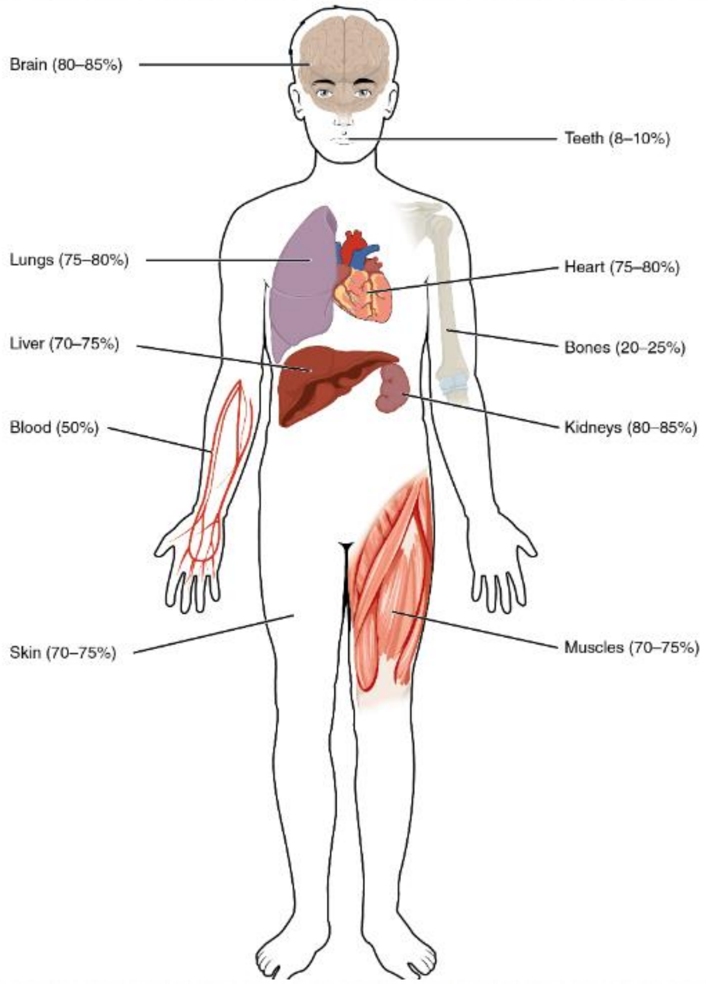
- *The body maintains a delicate balance between acidity and alkalinity, measured by pH levels. The ideal pH range is slightly alkaline (7.35-7.45).
- Electrolytes' role in acid-base balance
- :*1. *Bicarbonate (HCO3-):
- Helps neutralize acids, maintaining alkalinity.2. *Hydrogen ions (H+)*: Contribute to acidity.3. *Potassium (K+)*: Helps regulate bicarbonate levels.4. *Sodium (Na+)*: Influences bicarbonate reabsorption in the kidneys.*How electrolytes maintain acid-base balance:*

INTRODUCTION

- Body Fluids and Fluid Compartment
- The chemical reactions of life take place in aqueous solutions. The dissolved substances in a solution are called solutes. In the human body, solutes vary in different parts of the body, but may include proteins including those that transport lipids, carbohydrates, and, very importantly, electrolytes.
- Often in medicine, a mineral dissociated from a salt that carries an electrical charge (an ion) is called and electrolyte.
- For instance, sodium ions (Na^+) and chloride ions (Cl^-) are often referred to as electrolytes
- In the body, water moves through semi-permeable membranes of cells and from one compartment of the body to another by a process called osmosis
- Osmosis is basically the diffusion of water from regions of higher concentration to regions of lower concentration, along an osmotic gradient across a semi-permeable membrane

Body Water Content

- Human beings are mostly water, ranging from about 7 percent of body mass in infants to about 50–60 percent adult men and women, to as low as 45 percent in old age.
- The percent of body water changes with developmen because the proportions of the body given over to eac organ and to muscles, fat, bone, and other tissues chang from infancy to adulthood Your brain and kidneys have th highest proportions of water, which composes 80–85 perce of their masses.
- In contrast, teeth have the lowest proportion of water, at 8 10 percent



Acid-Base Balance

- roper physiological functioning depends on a very tight balance between the concentrations of acids and bases in the blood. Acid-balance balance is measured using the pH scale.
- A variety of buffering systems permits blood and other bodily fluids to maintain a narrow pH range, even in the face of perturbations. A buffer is a chemical system that prevents a radical change in fluid pH by dampening the change in hydrogen ion concentrations in the case of excess acid or base.
- Most commonly, the substance that absorbs the ions is either a weak acid, which takes up hydroxyl ions, or a weak base, which takes up hydrogen ions

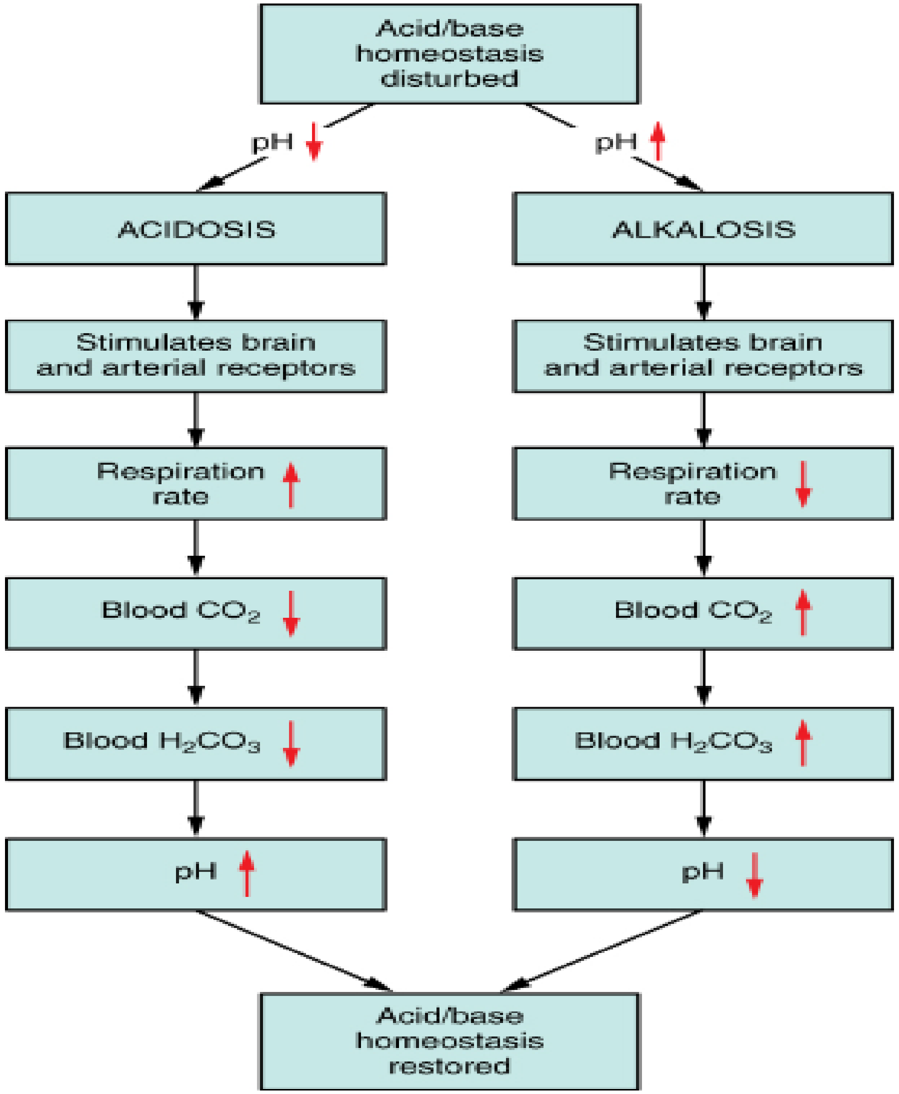
Buffer Systems in the Body

- The buffer systems in the human body are extremely efficient, and different systems work at different rates. It takes only seconds for the chemical buffers in the blood to make adjustments to pH.
- The respiratory tract can adjust the blood pH upward in minutes by exhaling CO_2 from the body. The renal system can also adjust blood pH through the excretion of hydrogen ions (H^+) and the conservation of bicarbonate, but this process takes hours to days to have an effect.
- The buffer systems functioning in blood plasma include plasma proteins, phosphate, and bicarbonate and carbonic acid buffers. The kidneys help control acid-base balance by excreting hydrogen ions and generating bicarbonate that helps maintain blood plasma pH within a normal range. Protein buffer systems work predominantly inside cells

Respiratory Regulation of Acid-Base Balance

- The respiratory system contributes to the balance of acids and bases in the body by regulating the blood levels of carbonic acid (Figure 26.4.226.4.2). CO_2 in the blood readily reacts with water to form carbonic acid, and the levels of CO_2 and carbonic acid in the blood are in equilibrium
- When the CO_2 level in the blood rises (as it does when you hold your breath), the excess CO_2 reacts with water to form additional carbonic acid, lowering blood pH.
- Increasing the rate and/or depth of respiration (which you might feel the "urge" to do after holding your breath) allows you to exhale more CO_2. The loss of CO_2 from the body reduces blood levels of carbonic acid and thereby adjusts the pH upward, toward normal levels

Respiratory Regulation of Blood pH. The respiratory system can reduce blood pH by removing CO_2 from the blood



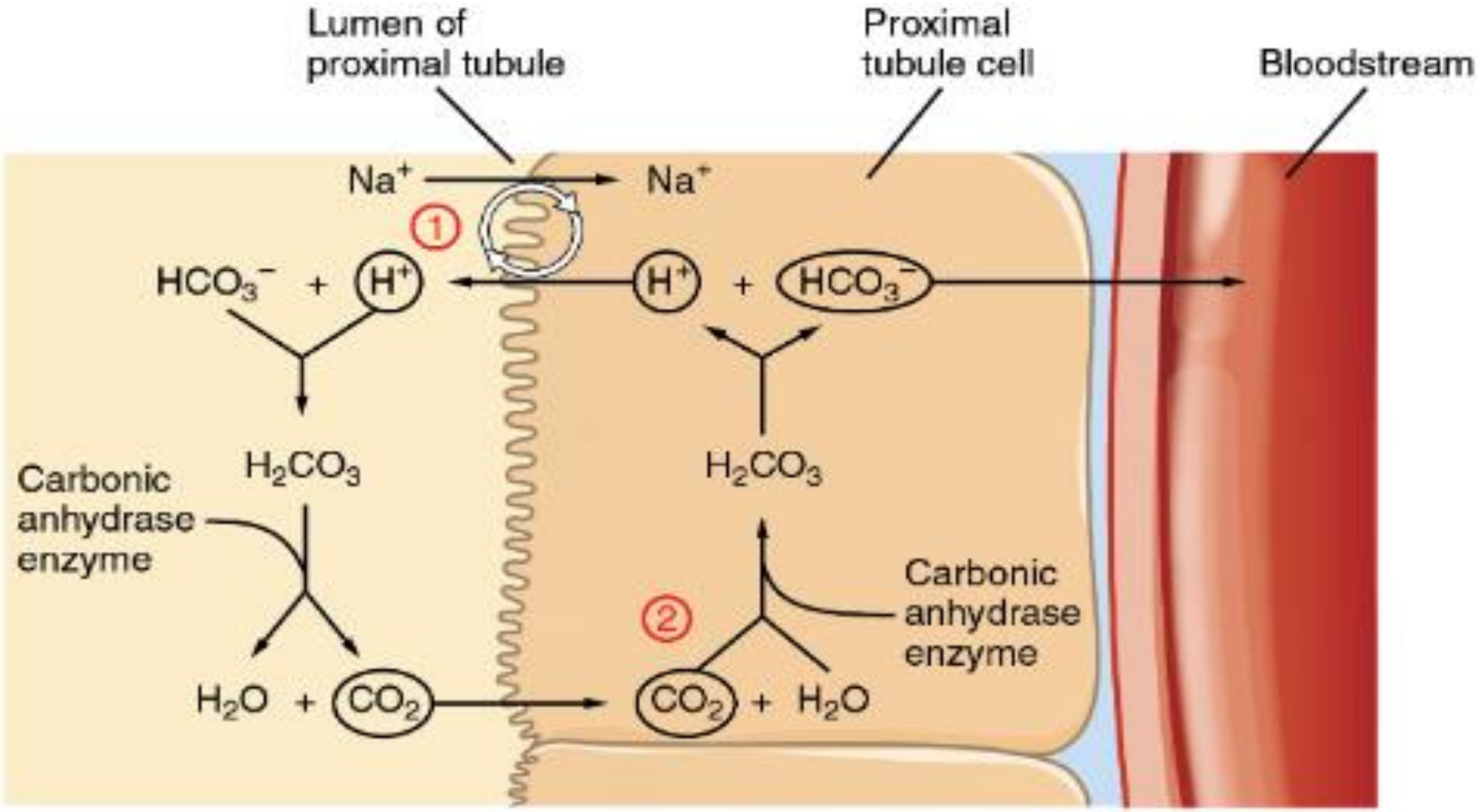
Renal Regulation of Acid-Base Balance

- he renal regulation of the body’s acid-base balance addresses the metabolic component of the buffering system.
- Whereas the respiratory system (together with breathing centers in the brain) controls the blood levels of carbonic acid by controlling the exhalation of CO_2, the renal system controls the blood levels of bicarbonate
- A decrease of blood bicarbonate can result from the inhibition of carbonic anhydrase by certain diuretics or from excessive bicarbonate loss due to diarrhea. Blood bicarbonate levels are also typically lower in people who have Addison’s disease (chronic adrenal insufficiency), in which aldosterone levels are reduced, and in people who have renal damage, such as chronic nephritis.
- Finally, low bicarbonate blood levels can result from elevated levels of ketones (common in unmanaged diabetes mellitus), which bind bicarbonate in the filtrate and prevent its conservation

Bicarbonate ions, HCO3-, found in the filtrate, are essential to the bicarbonate buffer system, yet the cells of the tubule are not permeable to bicarbonate ions. The steps involved in supplying bicarbonate ions to the system are seen in and are summarized below:

- Step 1: Sodium ions are reabsorbed from the filtrate in exchange for H^+ by an antiport mechanism in the apical membranes of cells lining the renal tubule.
- Step 2: The cells produce bicarbonate ions that can be shunted to peritubular capillaries.
- Step 3: When CO_2 is available, the reaction is driven to the formation of carbonic acid, which dissociates to form a bicarbonate ion and a hydrogen ion.
- Step 4: The bicarbonate ion passes into the peritubular capillaries and returns to the blood. The hydrogen ion is secreted into the filtrate, where it can become part of new water molecules and be reabsorbed as such, or removed in the urine

Conservation of Bicarbonate in the Kidney. Tubular cells are not permeable to bicarbonate; thus, bicarbonate is conserved rather than reabsorbed. Steps 1 and 2 of bicarbonate conservation are indicated



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- It is also possible that salts in the filtrate, such as sulfates, phosphates, or ammonia, will capture hydrogen ions. If this occurs, the hydrogen ions will not be available to combine with bicarbonate ions and produce CO_2. In such cases, bicarbonate ions are not conserved from the filtrate to the blood, which will also contribute to a pH imbalance and acidosis.
- The hydrogen ions also compete with potassium to exchange with sodium in the renal tubules. If more potassium is present than normal, potassium, rather than the hydrogen ions, will be exchanged, and increased potassium enters the filtrate. When this occurs, fewer hydrogen ions in the filtrate participate in the conversion of bicarbonate into CO_2 and less bicarbonate is conserved. If there is less potassium, more hydrogen ions enter the filtrate to be exchanged with sodium and more bicarbonate is conserved.
- Chloride ions are important in neutralizing positive ion charges in the body. If chloride is lost, the body uses bicarbonate ions in place of the lost chloride ions. Thus, lost chloride results in an increased reabsorption of bicarbonate by the renal system

Disorders of Acid base balance-Ketoacidosis

Diabetic acidosis, or ketoacidosis, occurs most frequently in people with poorly controlled diabetes mellitus. When certain tissues in the body cannot get adequate amounts of glucose, they depend on the breakdown of fatty acids for energy.

When acetyl groups break off the fatty acid chains, the acetyl groups then non-enzymatically combine to form ketone bodies, acetoacetic acid, beta-hydroxybutyric acid, and acetone, all of which increase the acidity of the blood.

In this condition, the brain isn't supplied with enough of its fuel glucose to produce all of the ATP it requires to function

Ketoacidosis can be severe and, if not detected and treated properly, can lead to diabetic coma which can be fatal

Symptom of ketoacidosis

- Rapid breathing as the body attempts to drive off CO_2 and compensate for the acidosis
- Fruity-smelling breath, due to the exhalation of acetone
- Dry skin and mouth
- A flushed face, nausea
- Vomiting
- Stomach pain

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THANK YOU