

# Common Laboratory Tests

# Let's look at some nuances of 3 of most commonly ordered lab tests

- CBC (Complete Blood Count)
  - with or without differential
- BMP (Basic Metabolic Panel)
- CMP (Comprehensive Metabolic Panel)

# CBC

- Complete blood count
  - With or without differential
- Peripheral venous blood is collected in a lavender tube (contains the anticoagulant EDTA) and should be thoroughly mixed
- Unacceptable specimen:
  - Clotted or greater than 48 hours old
- Methodology of testing:
  - Whole blood analyzer
- How often is the test available for hospitalized patients?
  - 7 days/week (24/7)

# What is measured?

- Red blood cell data
  - Total red blood cell count (RBC)
  - Hemoglobin (Hgb)
  - Hematocrit (Hct)
  - Mean corpuscular volume (MCV)
  - Red blood cell distribution width (RDW)
- White blood cell data
  - Total white blood cell (leukocyte) count (WBC)
  - A white blood cell count differential may also be ordered
- Platelet Count (PLT)

# Total Red Blood Cell Count

- Count of the number of circulating red blood cells in  $1\text{mm}^3$  of peripheral venous blood

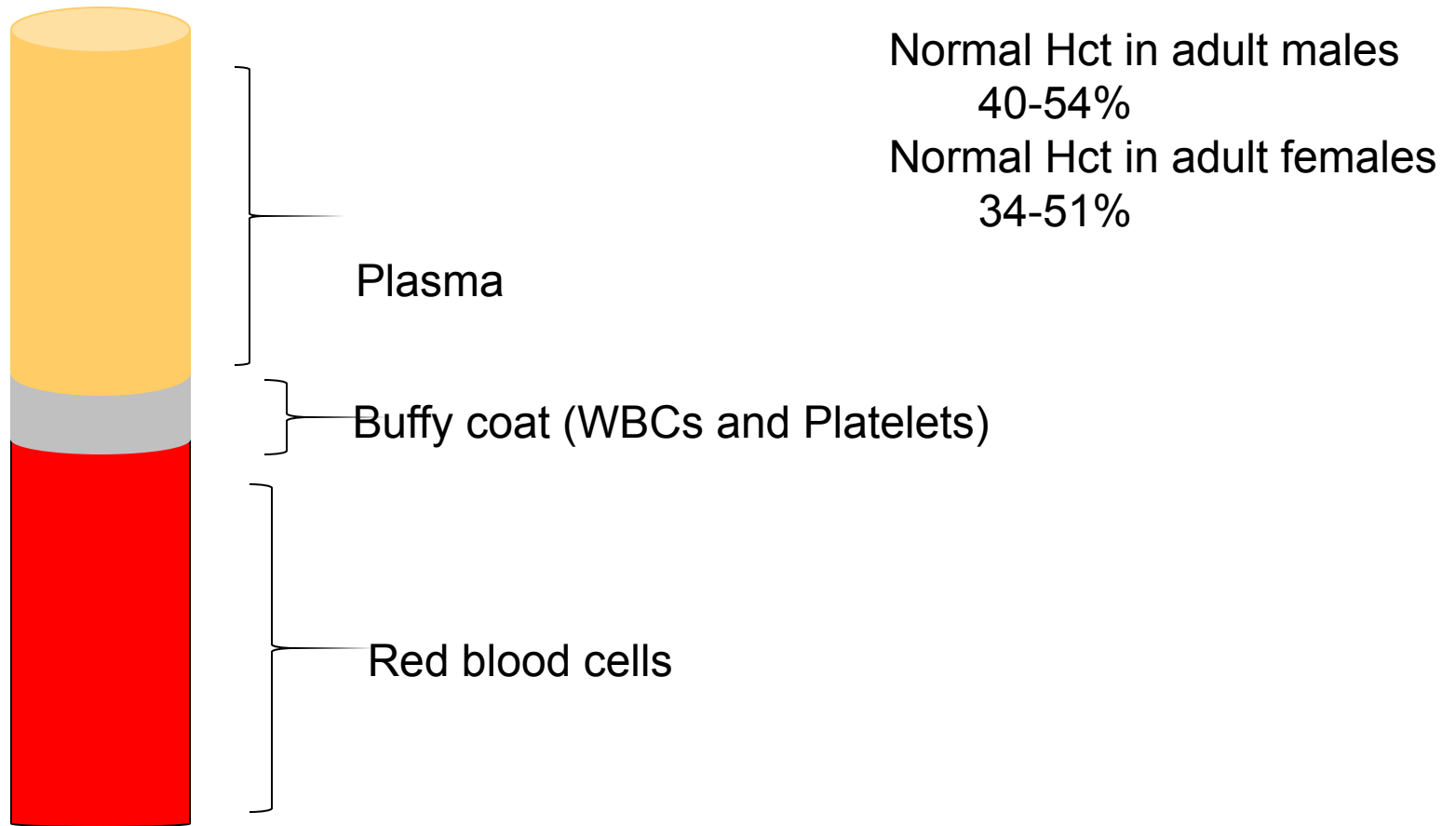
# Hemoglobin

- The hemoglobin concentration is a measure of the amount of Hgb in the peripheral blood, which reflects the number of red blood cells in the blood
  - Hgb constitutes over 90% of the red blood cells
- Decrease in Hgb concentration =
  - anemia
- Increase in Hgb concentration =
  - polycythemia

# Hematocrit

- Hematocrit is a measure of the percentage of the total blood volume that is made up by the red blood cells
- The hematocrit can be determined directly by centrifugation (“spun hematocrit”)
  - The height of the red blood cell column is measured and compared to the column of the whole blood

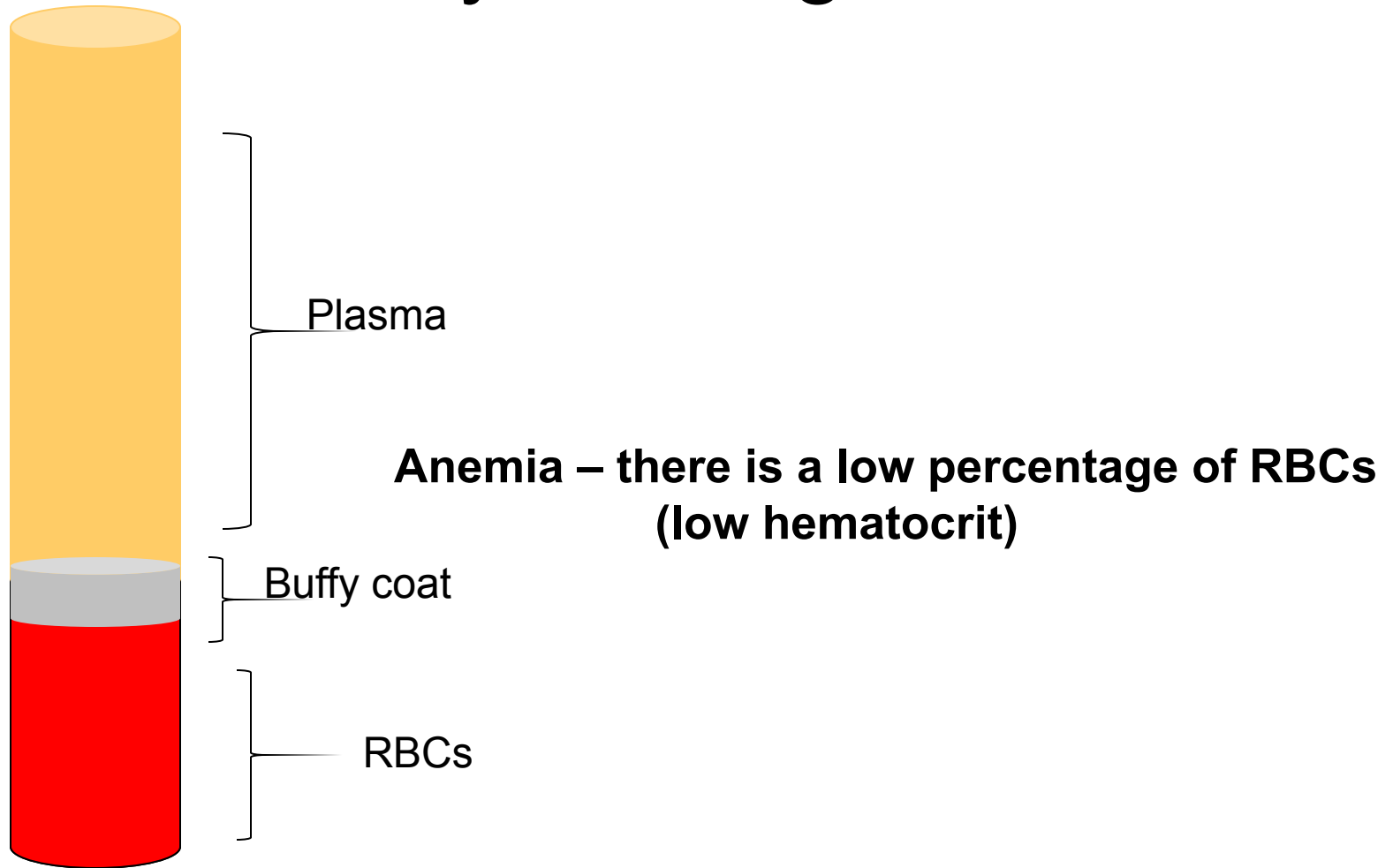
# Centrifuged blood (normal)





# Centrifuged blood (adult male or female)

## What is your diagnosis?



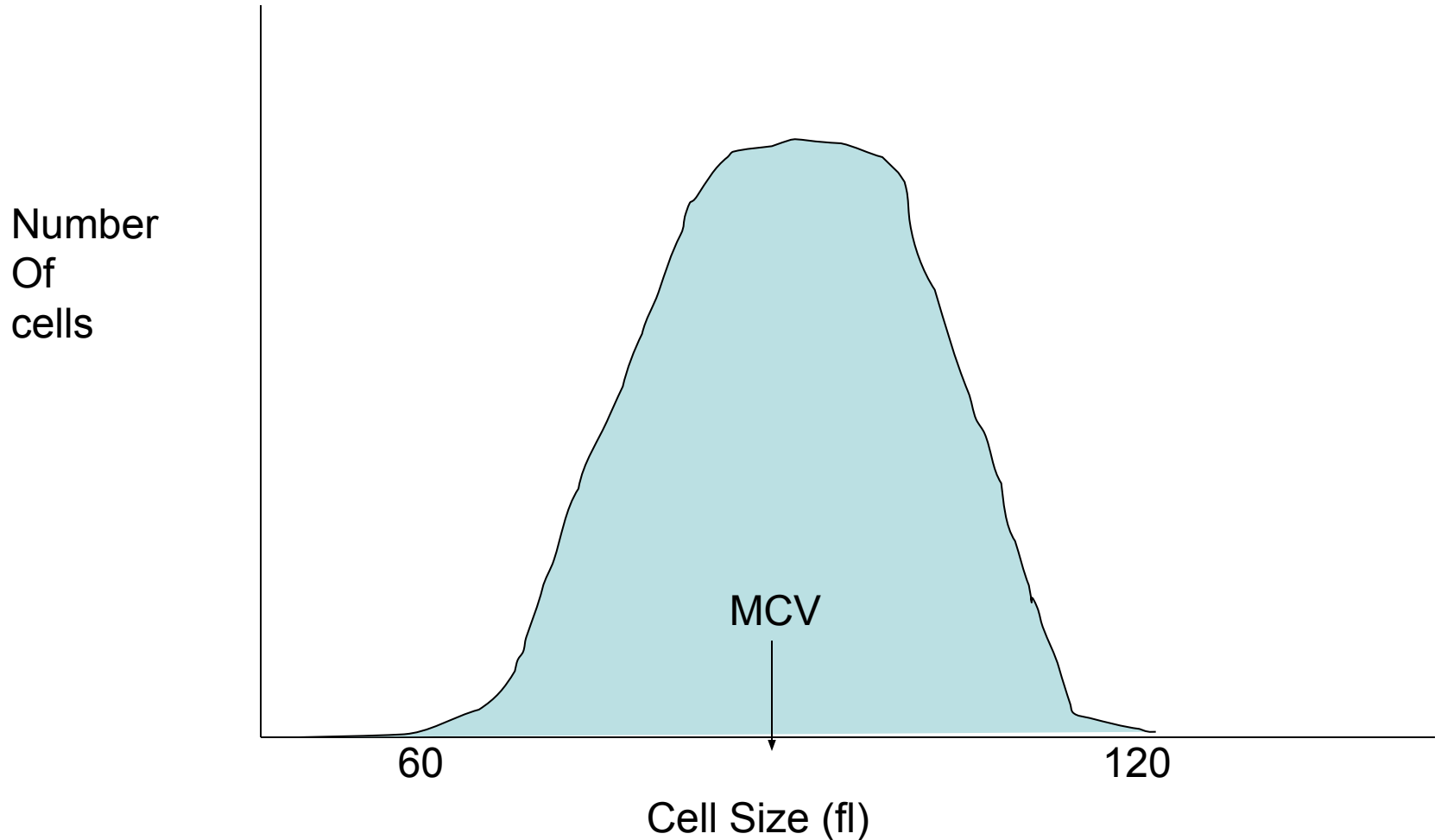
# Calculating the Hematocrit

- More commonly the Hct is calculated directly from the RBC and MCV
  - Hematocrit % =  $\text{RBC (cells/liter)} \times \text{MCV (liter/cell)}$
- Because the Hct is a derived value, errors in the RBC or MCV determination will lead to spurious results

# Mean Corpuscular Volume

- The MCV is a measure of the average volume, or size, of an RBC
- It is determined by the distribution of the red blood cell histogram
  - The mean of the red blood cell distribution histogram is the MCV

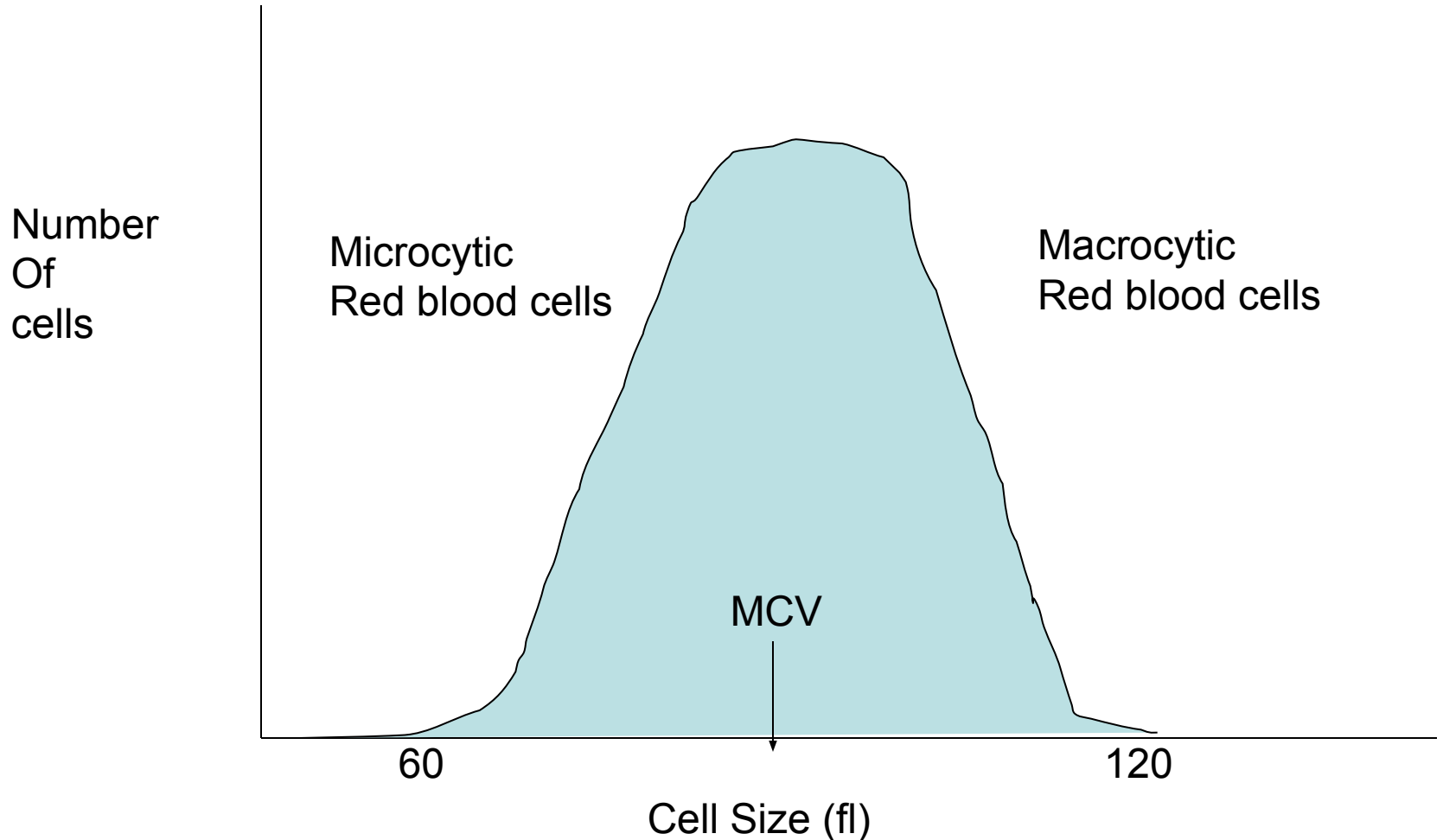
# Red Cell Distribution Histogram



# Use of MCV Result

- The MCV is important in classifying anemias
  - Normal MCV = normocytic anemia
  - Decreased MCV = microcytic anemia
  - Increased MCV = macrocytic anemia

# Red Cell Distribution Histogram



# Red Blood Cell Distribution Width

- RDW is an indication of the variation in the RBC size (referred to anisocytosis)
- It is derived from the red blood cell histogram and represents the coefficient of variation of the curve
- In general, an elevated RDW (indicating more variation in the size of RBCs) has been associated with anemias with various deficiencies, such as iron, B12, or folate
- Thalassemia is a microcytic anemia that characteristically has a normal RDW

# White Blood Cell Count

- A count of the **total** WBC, or leukocyte, count in  $1\text{mm}^3$  of peripheral blood
- A decrease in the number of WBCs =
  - Leukopenia
- An increase in the number of WBCs =
  - Leukocytosis



# WBC Differential

- When a differential is ordered, the percentage of each type of leukocyte present in a specimen is measured.
- Name the types of leukocytes
  - Neutrophils (includes bands)
  - Lymphocytes
  - Monocytes
  - Eosinophils
  - Basophils
- WBC differentials are either performed manually or by an automated instrument

# Manual Differentials

- “Manual” WBC differentials are performed by trained medical technologists who count and categorize typically 100 white blood cells via microscopic examination of a Romanowsky-stained peripheral blood smear
  - In addition to the differential count, evaluation of the smear provides the opportunity to morphologically evaluate all components of the peripheral blood, including red blood cells, white blood cells and platelets
    - The manual differential allows for the detection of disorders that might otherwise be lost in a totally automated system
    - This applies to < 20% of specimens
    - The instrument is programmed with criteria to flag an operator when a manual differential should be performed

# Automated Differentials

- The clinical laboratory may perform an “automated differential”
  - Via instruments with the capability of performing differential leukocyte counts
    - Usually based on the determination of different leukocyte cellular characteristics that permit separation into subtypes by using flow-cytometric techniques

# Platelet Count (PLT)

- A count of the number of platelets (thrombocytes) per cubic milliliter of blood
  - A decreased number of platelets =
    - Thrombocytopenia
  - An increased number of platelets =
    - Thrombocytosis

## CBC as reported by LUMC Lab in the EPIC EMR

| Component           |      | Value | Flag | Low  | High | Units |
|---------------------|------|-------|------|------|------|-------|
| WBC                 | 9.4  | 4.0   |      | 10.0 |      | K/UL  |
| RBC                 | 4.81 | 3.60  |      | 5.50 |      | M/UL  |
| HGB                 | 13.7 | 12.0  |      | 16.0 |      | GM/DL |
| HCT                 | 41.1 | 34.0  |      | 51.0 |      | %     |
| MCV                 | 85.4 | 85    |      | 95   |      | FL    |
| MCH                 | 28.6 | 28.0  |      | 32.0 |      | PG    |
| MCHC                | 33.4 | 32.0  |      | 36.0 |      | GM/DL |
| RDW                 | 14.3 | 11.0  |      | 15.0 |      | %     |
| PLT CNT             | 220  |       |      | 150  | 400  | K/UL  |
| DIFF TYPE AUTOMATED |      |       |      |      |      |       |
| LYMPH #             | 3.6  |       |      | 1.0  | 4.0  | K/MM3 |
| MONO #              | 0.6  |       |      | 0.0  | 1.0  | K/MM3 |
| GRAN #              | 5.1  |       |      | 2.0  | 7.0  | K/MM3 |
| EO #                | 0.0  |       |      | 0.0  | 0.7  | K/MM3 |
| BASO #              | 0.0  |       |      | 0.0  | 0.2  | K/MM3 |
| LYMPH               | 39   |       |      | 20   | 45   | %     |
| MONO                | 6    |       |      | 0    | 10   | %     |
| GRAN                | 55   |       |      | 45   | 70   | %     |
| EO                  | 0    | 0     |      | 7    |      | %     |
| BASO                | 0    |       |      | 0    | 2    | %     |

# MCH and MCHC

Note:

Both MCH and MCHC are of little clinical diagnostic use in the vast majority of patients (so we did not talk about them in any detail)

- MCH is the hemoglobin concentration per cell
- MCHC is the average hemoglobin concentration per total red blood cell volume

# Interpretation?

Essentially normal CBC

WBC, Hgb, Hct, MCV, RDW, PLT count values are all within the normal reference ranges

The automated differential shows normal distribution (total and percentage) of WBC components

See next slide for more explanation

**Absolute numbers (#) of various cell types are calculated by multiplying the percentage (%) of the white cell by the total WBC.**

DIFF TYPE AUTOMATED

|             |     |     |       |
|-------------|-----|-----|-------|
| LYMPH # 3.6 | 1.0 | 4.0 | K/MM3 |
| MONO # 0.6  | 0.0 | 1.0 | K/MM3 |
| GRAN # 5.1  | 2.0 | 7.0 | K/MM3 |
| EO # 0.0    | 0.0 | 0.7 | K/MM3 |
| BASO # 0.0  | 0.0 | 0.2 | K/MM3 |
| LYMPH 39    | 20  | 45  | %     |
| MONO 6      | 0   | 10  | %     |
| GRAN 55     | 45  | 70  | %     |
| EO 0        | 0   | 7   | %     |
| BASO 0      | 0   | 2   | %     |

For example, there are 39% lymphocytes.

The total number of WBC is 9,400 (see CBC)

$$9,400 \times 0.39 = 3,666$$

Therefore, the absolute lymphocyte count is 3.6 K/MM3



# Interpret this CBC

## CBC

|           |      |                   |
|-----------|------|-------------------|
| WBC       | 19.5 | [4.0-10.0] k/ul   |
| RBC       | 3.49 | [3.60-5.50] m/ul  |
| Hgb       | 10.4 | [12.0-16.0] gm/dl |
| Hct       | 31.2 | [34.0-51.0] %     |
| MCV       | 82   | [85-95] fl        |
| MCH       | 28.3 | [28.0-32.0] pg    |
| MCHC      | 33.3 | [32.0-36.0] gm/dl |
| RDW       | 16.6 | [11.0-15.0] %     |
| Plt Count | 98   | [150-400] k/ul    |

# Common Clinical Uses of CBC

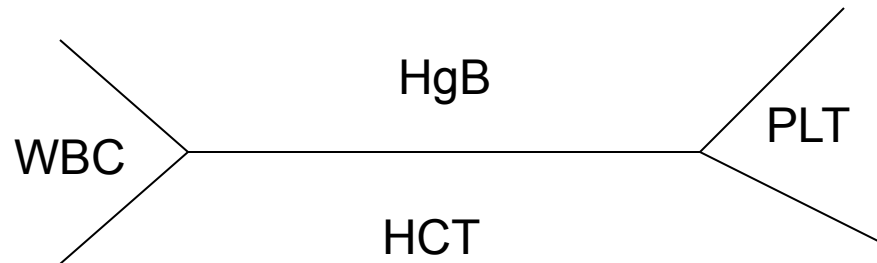
- CBC demonstrates
  - Leukocytosis
  - Microcytic anemia with elevated red cell distribution width
  - Thrombocytopenia

During MHD you will learn disease processes that cause these aberrations and develop differential diagnoses for them

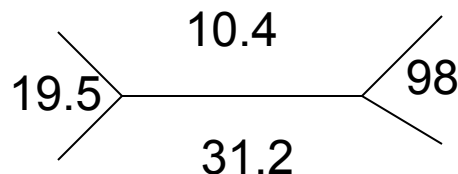
Your skills in lab interpretation will develop as the course evolves and you work through your small group and lab cases

# One final CBC pearl

- Clinicians have a short-hand way to report CBC values:



If we look again at the last CBC...



# BMP

(Basic Metabolic Panel)

# BMP

- The BMP is a chemistry panel where multiple chemistry tests are grouped as a single profile for ease of ordering since this group of tests are often all medically necessary.
- The BMP includes electrolytes and tests of kidney function:
  - Sodium (Na)
  - Potassium (K)
  - Chloride (Cl)
  - Carbon Dioxide Content (CO<sub>2</sub>)
  - Blood Urea Nitrogen (BUN)
  - Serum Creatinine (Cr)
  - Serum glucose (Glu)
  - Total Calcium (Calcium)

# BMP

- Peripheral venous blood can be collected in several types of tube
  - **Light Green PST**
    - Plasma separating tube (PST) with the anticoagulant lithium heparin
  - **Gold SST**
    - Serum separating tube (SST) contains a gel at the bottom to separate blood cellular components from serum on centrifugation
  - **Red**
    - No Additives – blood clots and serum is separated by centrifugation
- How often is the lab test available for hospitalized patients?
  - 7 days/week (24/7)

# Sodium

- Sodium is the major cation in the extracellular space where serum levels of approximately 140mmol/L exist
  - Sodium salts are major determinants of extracellular osmolality.
- Increased serum sodium level =
  - Hypernatremia
- Decreased serum sodium level =
  - Hyponatremia

# Potassium

- Potassium is the major intracellular cation with levels of ~ 4 mmol/L found in serum
  - Elevated serum potassium level =
    - Hyperkalemia
  - Decreased serum potassium level =
    - Hypokalemia
- \*note – if a specimen is hemolyzed (such as by traumatic venipuncture or drawing blood with a needle that is too small) potassium levels may be “falsely” elevated. Why?
- There are high concentrations of K in red blood cells. If RBCs are lysed during phlebotomy, K is released into the serum resulting in elevated measured levels.



# Chloride

- Chloride is the major extracellular anion with serum concentration of  $\sim 100$  mmol/L
- Hyperchloremia and hypochloremia are rarely isolated phenomena.
  - Usually they are part of shifts in sodium or bicarbonate to maintain electrical neutrality.

# Carbon Dioxide Content

- The carbon dioxide content (CO<sub>2</sub>) measures the H<sub>2</sub>CO<sub>3</sub>, dissolved CO<sub>2</sub> and bicarbonate ion (HCO<sub>3</sub><sup>-</sup>) that exists in the serum.
- Because the amounts of H<sub>2</sub>CO<sub>3</sub> and dissolved CO<sub>2</sub> in the serum are so small, the CO<sub>2</sub> content is an indirect measure of the HCO<sub>3</sub><sup>-</sup> anion
  - Therefore, clinicians most often refer to the CO<sub>2</sub> measurement in the BMP as the “bicarbonate level” or “bicarb level”

# Blood Urea Nitrogen

- The BUN measures the amount of urea nitrogen in the blood.
  - Urea is formed in the liver as the end product of protein metabolism and is transported to the kidneys for excretion.
  - Nearly all renal diseases can cause an inadequate excretion of urea, which causes the blood concentration to rise above normal.
  - The BUN is interpreted in conjunction with the creatinine test – these tests are referred to as “renal function studies”.

# Creatinine

- The creatinine test measures the amount of creatinine in the blood.
  - Creatinine is a catabolic product of creatine phosphate used in skeletal muscle contraction.
  - Creatinine, as with blood urea nitrogen, is excreted entirely by the kidneys and blood levels are therefore proportional to renal excretory function.

# Glucose

- Plasma glucose levels should be evaluated in relation to a patient's meal
  - i.e., postprandial vs fasting
  - Elevated glucose levels may also be indicative of diabetes mellitus
- Glucose is the most commonly measured test in the laboratory

# Diagnosing Diabetes

- The criteria for the diagnosis of diabetes:
  - Fasting Plasma Glucose  $\geq 126$  mg/dL
  - 2 hour Post-Prandial Glucose  $\geq 200$  mg/dl
  - Random Plasma Glucose  $> 200$  mg/dL in the presence of symptoms
- Any one of these criteria must be repeated on subsequent testing of a new specimen

# Total Calcium

- The total serum calcium is a measure of both
  - Free (ionized) calcium
  - Protein bound (usually to albumin) calcium
- Therefore, the total serum calcium level is affected by changes in serum albumin
  - As a rule of thumb, the total serum calcium level decreases by approximately 0.8mg for every 1gram decrease in the serum albumin level.

## **BMP as reported by LUMC Lab in the EPIC EMR**

| • Component  | Value | Flag | Low | High | Units |
|--------------|-------|------|-----|------|-------|
| • SODIUM     | 142   |      | 136 | 144  | MM/L  |
| • POTASSIUM  | 3.9   | 3.3  | 5.1 |      | MM/L  |
| • CHLORIDE   | 107   | 98   | 108 |      | MM/L  |
| • CO2        | 27    | 20   | 32  |      | MM/L  |
| • BUN        | 10    | 7    | 22  |      | MG/DL |
| • CREATININE | 0.80  |      | 0.7 | 1.5  | MG/DL |
| • GLUCOSE    | 100   |      | 70  | 100  | MG/DL |
| • CALCIUM    | 8.5   | L    | 8.9 | 10.3 | MG/DL |



# Your Interpretation?

- This patient has mild hypocalcemia
- Any other test you would like to order?
  - Serum albumin
    - If the serum albumin level is low, this would affect the total serum calcium level

# One final BMP pearl

- Clinicians have a short-hand way to report BMP values:

|    |     |     |     |
|----|-----|-----|-----|
| NA | Cl  | BUN | Glu |
| K  | CO2 | Cr  |     |

If we look at the last BMP...

|     |     |     |     |
|-----|-----|-----|-----|
| 142 | 107 | 10  | 100 |
| 3.9 | 27  | 0.8 |     |

# CMP

## (Complete Metabolic Panel)

# Complete Metabolic Panel

- The CMP provides a more extensive laboratory evaluation of organ dysfunction and includes:
  - Sodium
  - Potassium
  - Chloride
  - Carbon Dioxide Content
  - Albumin
  - Total Bilirubin
  - Total Calcium
  - Glucose
  - Alkaline Phosphatase
  - Total Protein
  - Aspartate Aminotransferase
  - Blood Urea Nitrogen
  - Creatinine

# Total Protein

- Albumin and globulin constitute most of the protein within the body and are measured in the total protein test

# Albumin

- Albumin comprises ~ 60% of the total protein within the extracellular portion of the blood (Hgb is the most abundant protein in whole blood and is intracellular)
- Albumin's major effect within the blood is to maintain colloid osmotic pressure
  - Transports many important blood constituents
    - drugs, hormones, enzymes
- Albumin is synthesized in the liver and therefore is a measure of hepatic function

# Alkaline Phosphatase

## (Alk Phos or ALP)

- Alkaline phosphatase is an enzyme present in a number of tissues, including liver, bone, kidney, intestine, and placenta, each of which contains distinct isoenzyme forms
- Isoenzymes are forms of an enzyme that catalyze the same reaction, but are slightly different in structure
- The two major circulating alkaline phosphatase isoenzymes are bone and liver.
  - Therefore elevation in serum alkaline phosphatase is most commonly a reflection of liver or bone disorders.
    - Levels of alk phos are increased in both extrahepatic and intrahepatic obstructive biliary disease

# Bilirubin, Total

- The total serum bilirubin level is the sum of the conjugated (direct) and unconjugated (indirect) bilirubin.
  - Normally the unconjugated bilirubin makes up 70-85% of the total bilirubin
- Remember that bilirubin metabolism begins with the breakdown of red blood cells in the reticuloendothelial system and bilirubin metabolism continues in the liver
  - Elevation in total bilirubin may therefore be a reflection of any aberrations in bilirubin metabolism or increased levels of bilirubin production (such as hemolysis)



# Aspartate Aminotransferase (AST)

- AST is an enzyme that is present in hepatocytes and myocytes (both skeletal muscle and cardiac)
  - Elevations in AST are most commonly a reflection of hepatocellular injury
    - But they may also be elevated in myocardial or skeletal muscle injury

The following CMP is from a patient who presented with systolic congestive heart failure exacerbation

Complete Metabolic Panel

|                        |     |   |              |        |
|------------------------|-----|---|--------------|--------|
| • Glucose              | 112 | H | [70 – 100]   | mg/dl  |
| • Blood Urea Nitrogen  | 39  | H | [7 - 22]     | mg/dl  |
| • Creatinine           | 1.6 | H | [0.7 - 1.5]  | mg/dl  |
| • Calcium              | 8.9 |   | [8.5 - 10.5] | mg/dl  |
| • Sodium               | 132 | L | [136 - 146]  | mmol/L |
| • Potassium            | 4.0 |   | [3.5 - 5.3]  | mmol/L |
| • Chloride             | 93  | L | [98 - 108]   | mmol/L |
| • Carbon Dioxide       | 23  |   | [20 - 32]    | mmol/L |
| • Albumin              | 3.1 | L | [3.6 - 5.0]  | gm/dl  |
| • Protein, Total       | 5.8 | L | [6.2 - 8.0]  | gm/dl  |
| • Alkaline Phosphatase | 200 |   | [25 - 215]   | IU/L   |
| • AST                  | 35  |   | [5 - 40]     | IU/L   |
| • Bilirubin, Total     | 1.9 | H | [0.2 - 1.4]  | mg/dl  |

# Interpretation?

(do not fret, you will begin learning this skill as MHD progresses and into your clerkships. This is only an example of how laboratory data will complement your understanding of pathophysiology!)

- BUN and creatinine are elevated with a BUN:Creat ratio greater than 20:1 consistent with pre-renal azotemia, the result of inadequate renal perfusion and resulting reduced urea clearance.
- Hepatic congestion leads to hypoxia and altered function of the liver cells. Bilirubin, especially the indirect fraction, and enzymes, like alkaline phosphatase, may be elevated. Total protein may decline at the expense of the decreased albumin produced in the liver.
- The electrolyte changes, especially hyponatremia, reflect a dilutional effect with water retention and decreased glomerular filtration rate (poor perfusion)
- Hyperglycemia is present but it is not known whether this was a fasting or random sample

# Final Comments...

- Excessive laboratory tests can cause iatrogenic anemia!
  - Although the goal of ordering any “blood test” is to help a patient, repeated blood collections, particularly in hospitalized patients, are a common cause of anemia.
  - Every test ordered, including lab tests, on a patient should be assessed for its benefits, risks and true need.

# Final Comments...

- No laboratory test should ever be ordered unless it is medically necessary

Thank  
You!!

