

# Blood Cells



“The blood is the life!”

- Bram Stoker's *Dracula*

# Overview

What is blood?

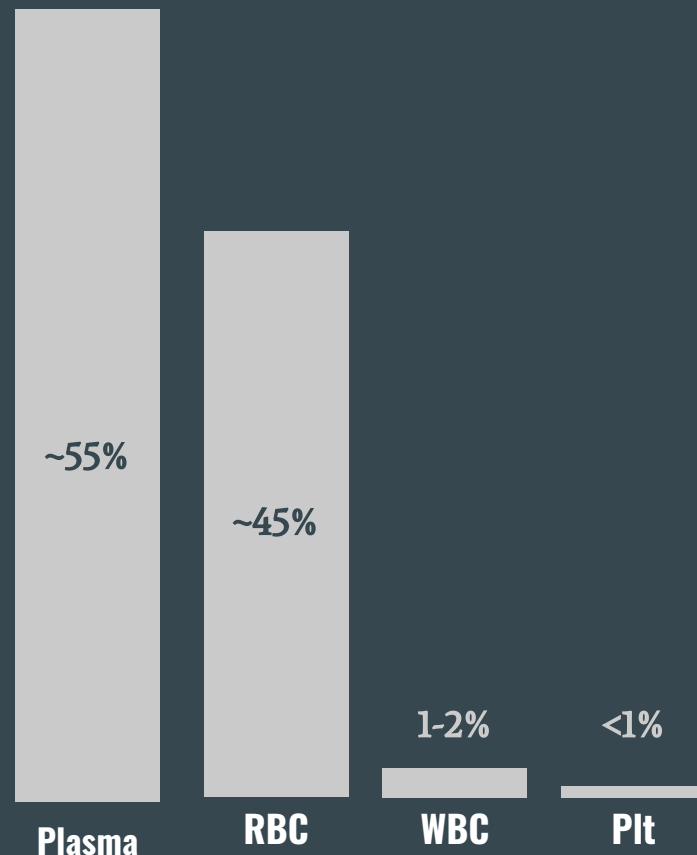
Components:

- Plasma
  - Red Blood Cells
  - White Blood Cells
  - Platelets
-

# Blood Percentages

What is in there anyway?

- “Juice” - the liquid part
  - Plasma ( ~55%)
- “Stuff” - the solid parts
  - Red Blood Cells (~45%)
  - White Blood Cells (~1-2%)
  - Platelets (<1%)



# Plasma

- Liquid component of blood
  - Mostly water (~92-95%)
  - Other non-cellular blood components
    - Dissolved proteins
    - Glucose
    - Clotting factors
      - Without these, it is “**serum**”
    - Electrolytes
    - Hormones
- Appearance
  - Straw to light amber in color
  - Abnormalities:
    - Brown-red color
      - From hemolysis
    - Opaqueness (can appear milky)
      - From an increased lipid content
    - Darker yellow-amber color
      - From increased bilirubin
- Functions
  - Circulate blood cells and components
    - Coagulation, immunity, blood pressure
  - Circulate cellular waste to be filtered/removed



# Plasma Variations



Normal Plasma

- Straw-colored
- Clear



Hemolytic Plasma

- Red-colored due to hemoglobin from lysed/broken cells
- Clear



Lipemic Plasma

- White or milky color
- Opaque



Icteric Plasma

- Darker yellow to amber color from increased bilirubin
- Clear

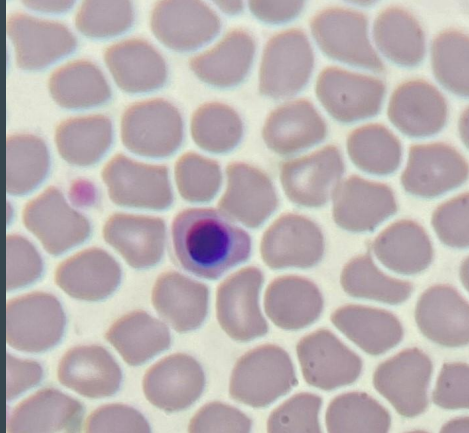
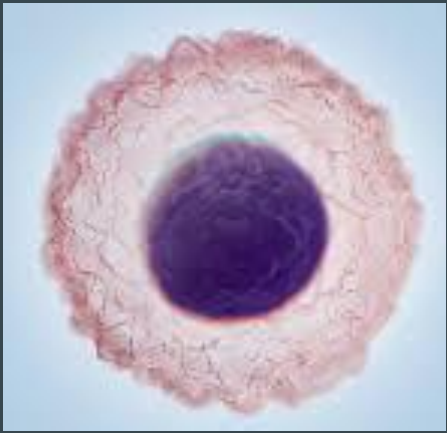
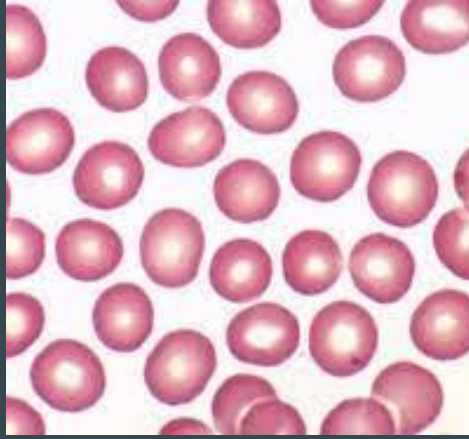
Plasma can also appear as a combination of these: hemolytic AND lipemic = strawberry milk appearance

# Red Blood Cells

- **Erythrocyte**
  - Erythro- means “red”
- **Morphology**
  - Normally uniform in size and shape
  - Biconcave disc shape (donut)
  - No nucleus - allows flexibility
- **Origin**
  - Formed in bone marrow
  - ~120 day lifespan
- **Function**
  - Contain hemoglobin
    - Protein that binds to and carries  $O_2$  to tissues and organs
    - Also delivers  $CO_2$  (waste) to lungs
- **Conditions**
  - Anemia = decreased number of RBCs
    - A- = lack of, absence of
    - -emia = blood



# RBCs

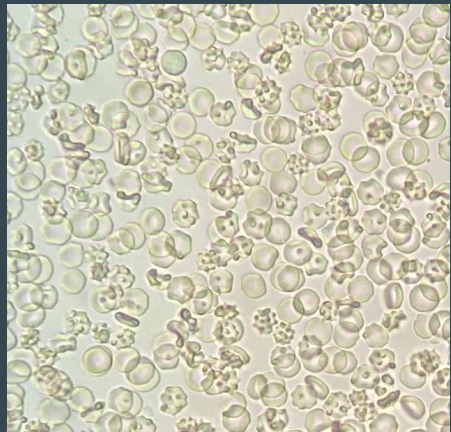
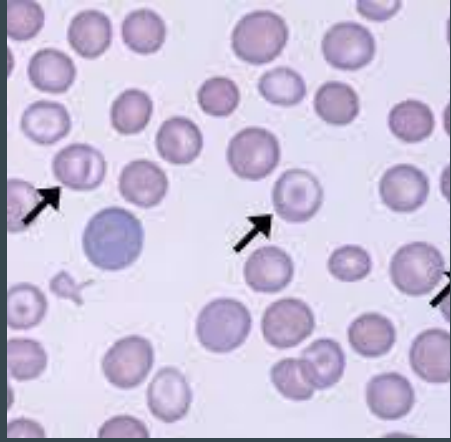


- Normal
  - Uniform in color and size (biconcave, central pallor)
  - Mature RBCs have no nucleus
    - Formation and maturation in marrow
    - Nucleus is ejected and dissolved
    - Now “empty” RBCs are flexible and escape portholes in marrow
    - Gain hemoglobin once circulating
- Abnormal = Nucleated RBCs (nRBCs)
  - Immature RBCs **do** have a nucleus
  - Why would we see these?
    - Damaged blood-bone barrier
      - Immature cells escape marrow
    - Hypoxia - stimulates RBC production
      - Anemia
      - Hemorrhage
      - CHF
    - Spleen dysfunction
      - Spleen normally filters nRBCs

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  - Production of RBCs outside of marrow
    - Liver or spleen can produce RBCs when desperate

# RBC Abnormalities



Some examples seen here:

- Polychromasia
- Anisocytosis
- Target cells (codocytes)
- Schistocytes
- Increased/decreased central pallor
- Crenation
  - Osmosis
- Rouleaux
  - “Stacked coins”

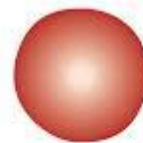
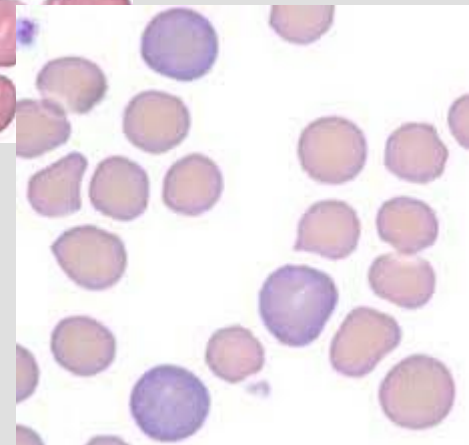
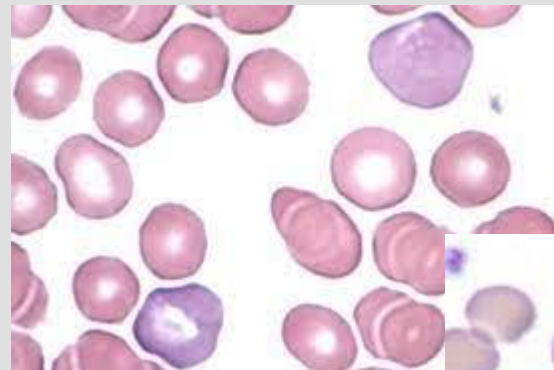
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# Red Blood Cell Abnormalities - Color

- **Polychromasia**

- Poly = multiple
  - chrom = color
- 
- Increased blue stain uptake in some cells on slide due to residual RNA
    - Immature RBCs released too early from bone marrow = reticulocytes
- 
- Conditions where you see this:
    - Hemolytic anemia
    - Hemorrhage
    - Hypoxia
    - Some cancers



Normal RBC

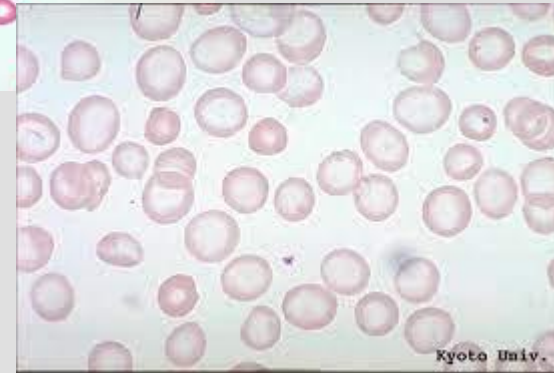
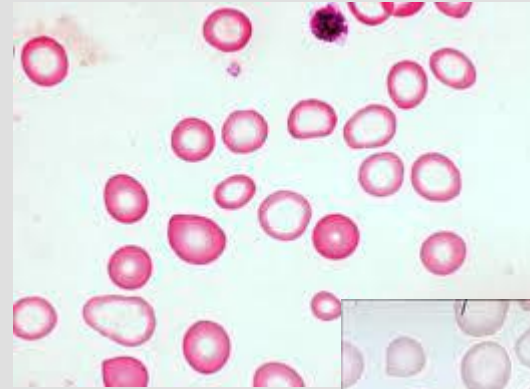


Polychromasia

# Red Blood Cell Abnormalities - Color

- **Hypochromasia**

- Hypo = less than normal
  - chrom = color
- 
- Rim of cytoplasm of RBCs is thinner than normal
    - Area of central pallor is larger
    - This appearance is due to lower hemoglobin content
- 
- Conditions where you see this:
    - Iron deficiency
    - Copper or B6 deficiency
    - Inhibited hemoglobin production



Normal RBC



Hypochromic  
RBC

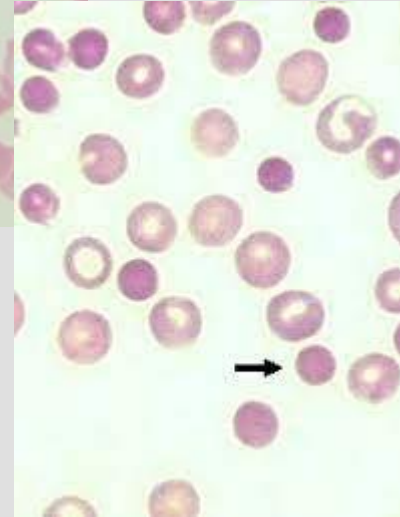
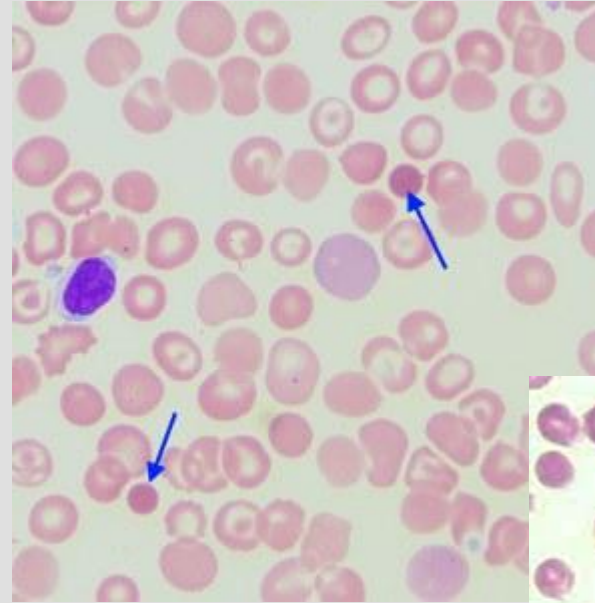


Severe  
Hypochromia

# Red Blood Cell Abnormalities - Color

- **Hyperchromasia**

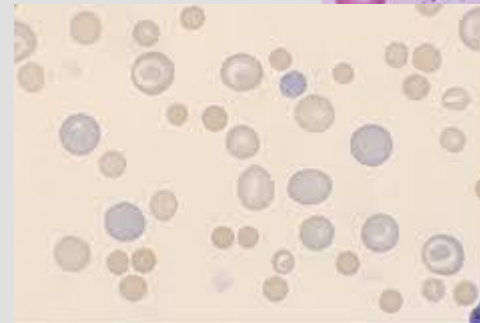
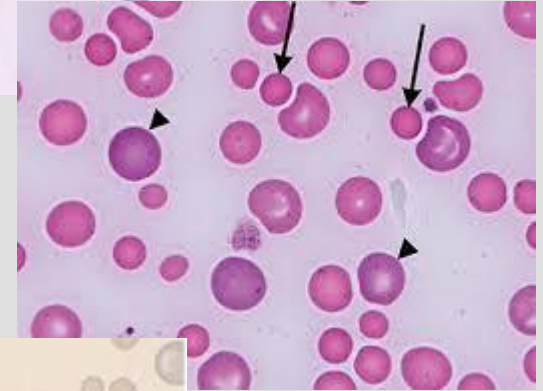
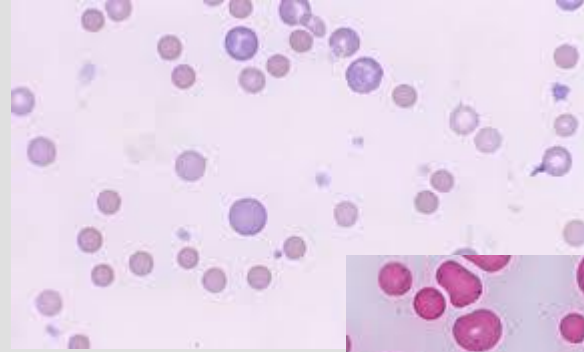
- Hyper = higher than normal
- chrom = color
- Cells appear a deeper red hue than normal
  - This appearance can be due to higher hemoglobin content
  - Spherocytes
    - Sphere-shaped (not donut) due to membrane
    - Smaller in diameter, so denser
- Conditions where you see this:
  - Hemolytic anemia  
(RBC membrane defect)
  - Low phosphorus
  - Snake bites



# Red Blood Cell Abnormalities - Size

- **Anisocytosis**

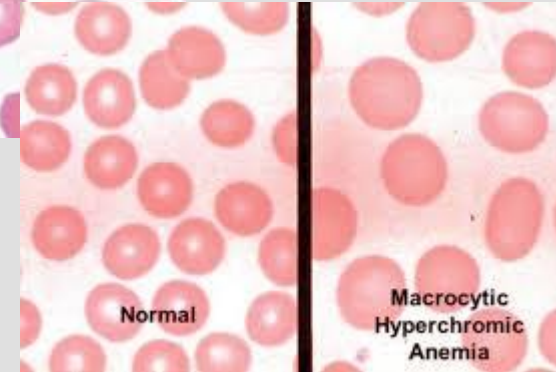
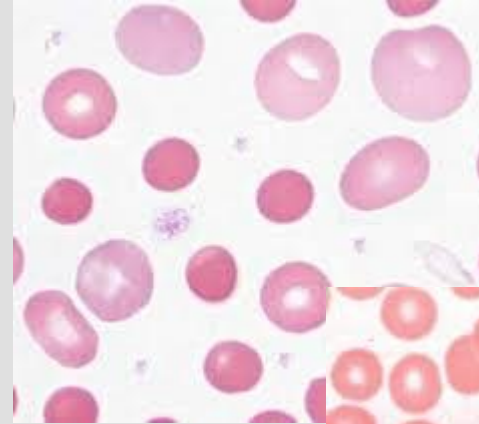
- An = not, lack of
  - iso = same/equal
  - cyt = cell
- Variation in red blood cell size
  - Conditions where you see this:
    - Anemias
      - Iron deficiency
      - Vitamin deficiency
    - Some cardiovascular diseases
    - Liver disease



# Red Blood Cell Abnormalities - Size

- **Macrocytosis**

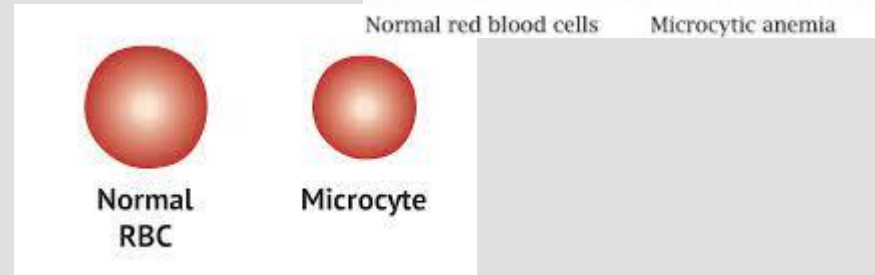
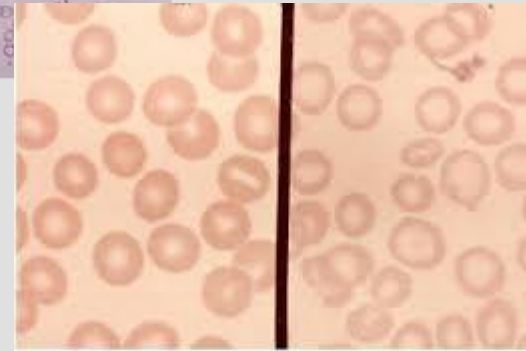
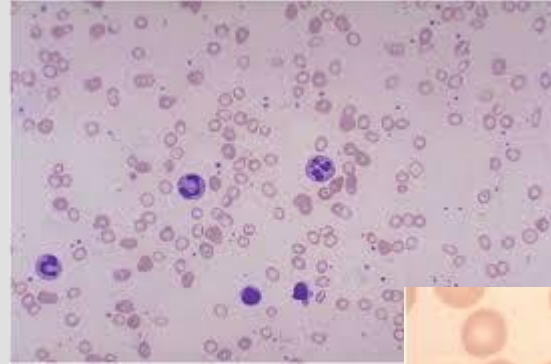
- Macro = large
  - cyt = cell
- Central pallor *can* be more difficult to discern
  - Conditions where you see this:
    - B-12 deficiency
    - Liver disease
    - Hypothyroidism
    - Side effect of some medications
    - Bone cancer



# Red Blood Cell Abnormalities - Size

- **Microcytosis**

- Micro = small
- cyt = cell
- Central pallor tends to be larger
- Conditions where you see this:
  - Iron deficiency
  - Some types of anemia
  - Lead toxicity

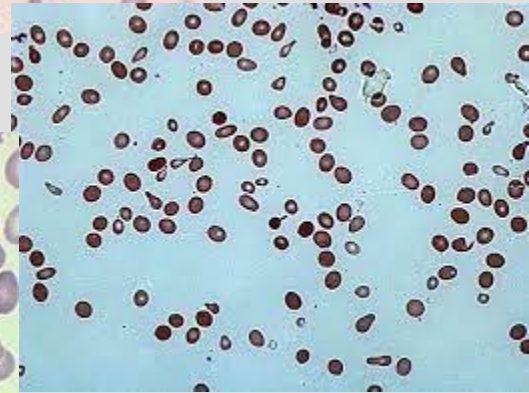
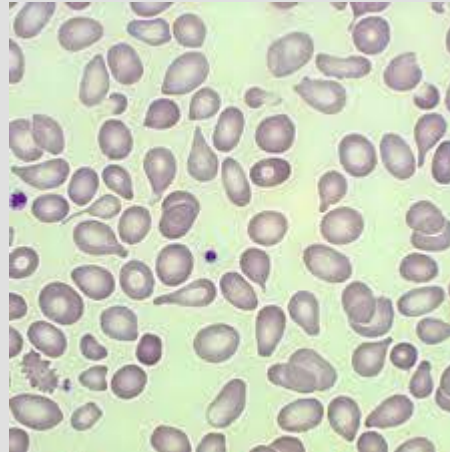
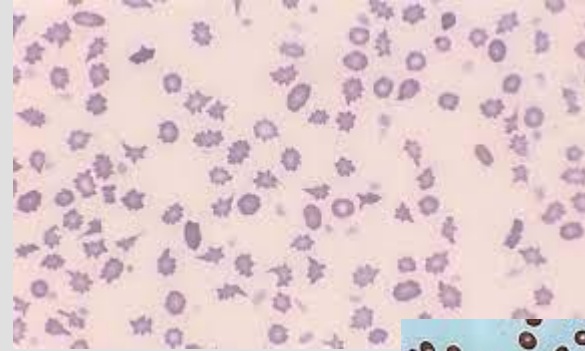




# Red Blood Cell Abnormalities - Shape

- **Poikilocytosis**

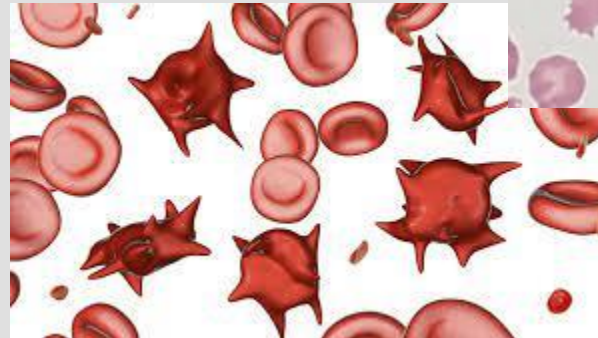
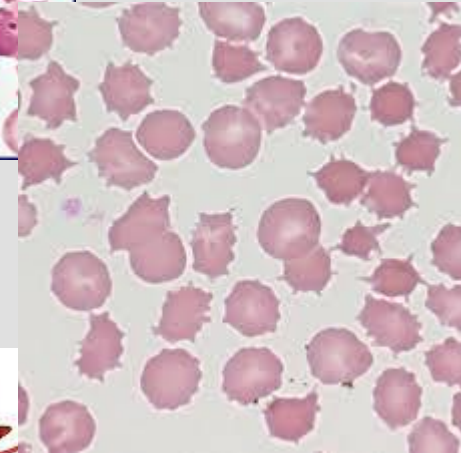
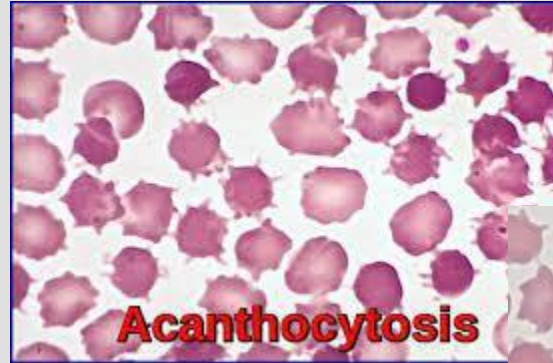
- Poikilos = varied
- cyt = cell
- Abnormal variation in cell shape
  - Used when describing abnormalities in >10% of a cell population
- Can be due to membrane abnormalities
- Can be due to trauma



# Red Blood Cell Abnormalities - Shape

- **Acanthocytes**

- Acantha = thorn
  - cyt = cell
- 
- Also called spur cells
  - Spiculated (spiked) RBCs with a few membrane projections of varying size and distribution
    - IRREGULAR spikes
  - Conditions where you see this:
    - After splenectomies
    - Liver disease
    - Hypothyroidism
    - Iron deficiency anemia
    - DIC

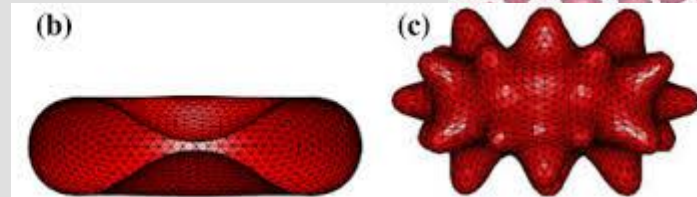
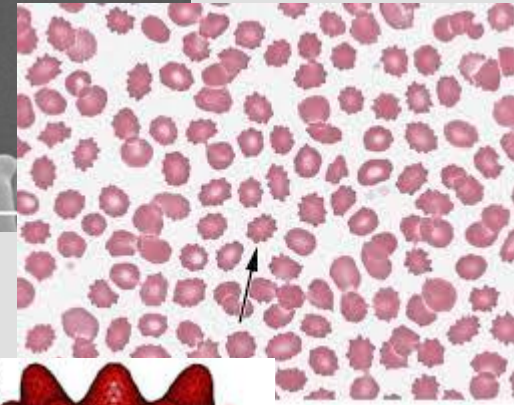
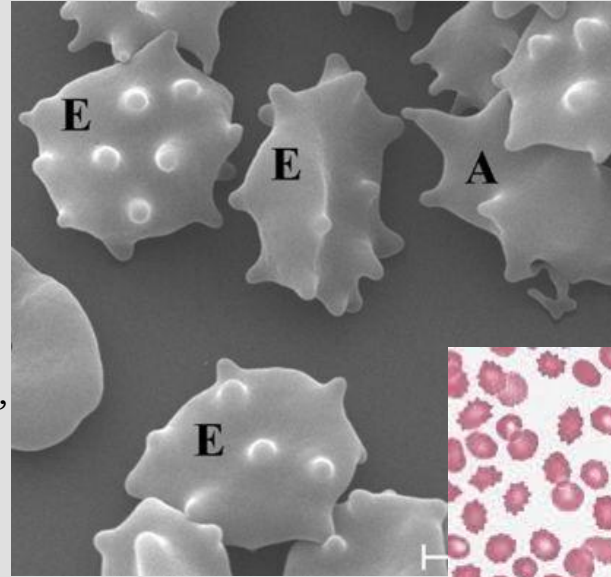




# Red Blood Cell Abnormalities - Shape

- **Echinocytes**

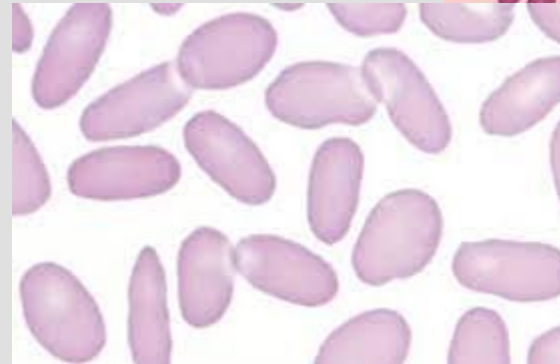
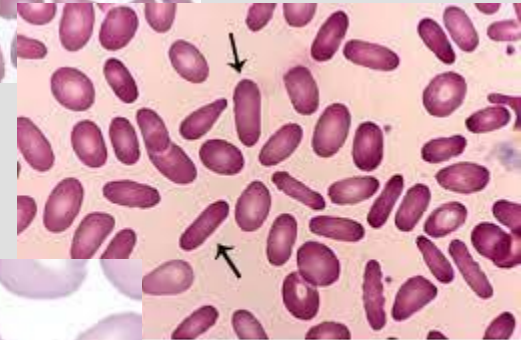
- Echinoc = hedgehog, sea urchin
- cyt = cell
- Crenated cells - artifact, throughout slide
- True Burr cells - less numerous
- Spiculated (spiked) RBCs with a many small, evenly spaced projections of the membrane
  - REGULAR spikes
- Conditions where you see this:
  - ARTIFACT from EDTA
  - Renal disease, uremia
  - Liver disease
  - Low phosphorus
  - ATP production disorders



# Red Blood Cell Abnormalities - Shape

- **Elliptocytes, Ovalocytes**

- Ellipto = oval
  - Ovalo = from Latin ovum = egg
  - cyt = cell
- 
- Oval or elongated RBCs with blunt ends
    - Varying degrees of elongation
- 
- Conditions where you see this:
    - Iron deficiency anemia
    - Genetic predisposition
      - Labradors
      - Chows
    - Liver disease
    - Renal disease



# Red Blood Cell Abnormalities - Shape

- **Codocytes**

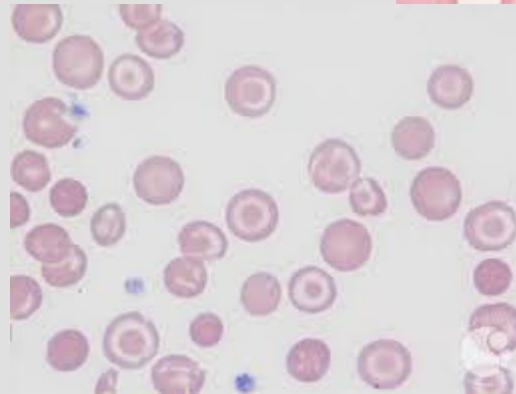
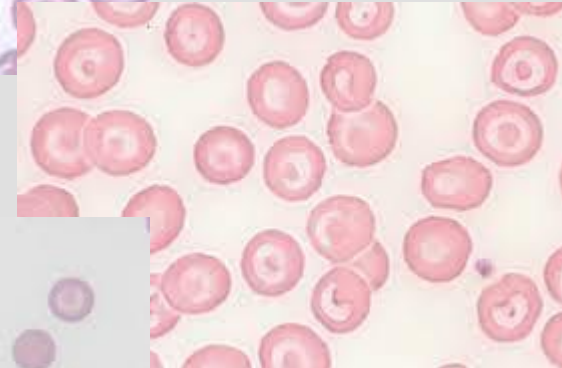
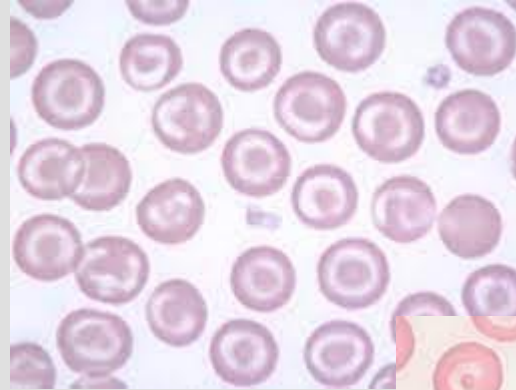
- Codo = bell (shape in blood)
- cyt = cell

- Target cells - appearance on slide

- Dark center of hemoglobin
- Excess surface membrane
- “Bull’s eye” appearance

- Conditions where you see this:

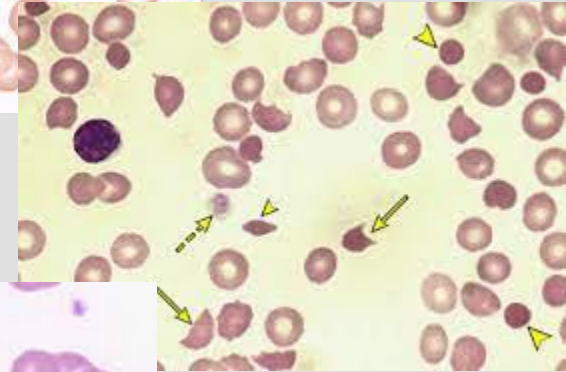
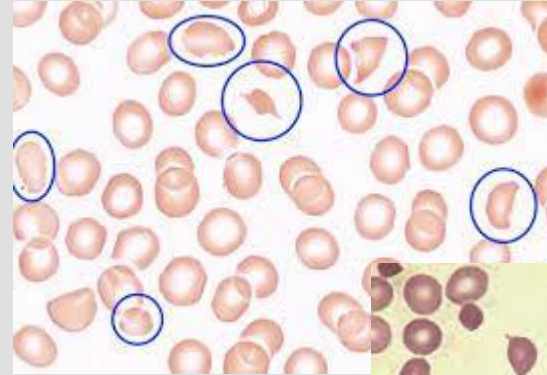
- Regenerative anemia
- Iron deficiency anemia
- Liver disease
- High cholesterol



# Red Blood Cell Abnormalities - Shape

- **Schistocytes**

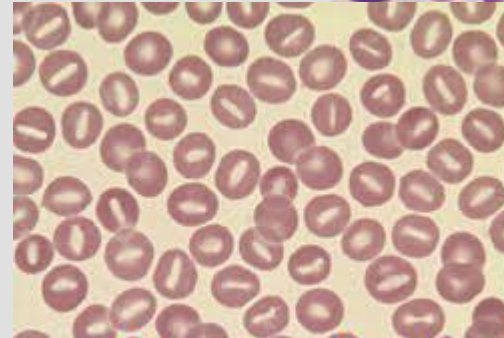
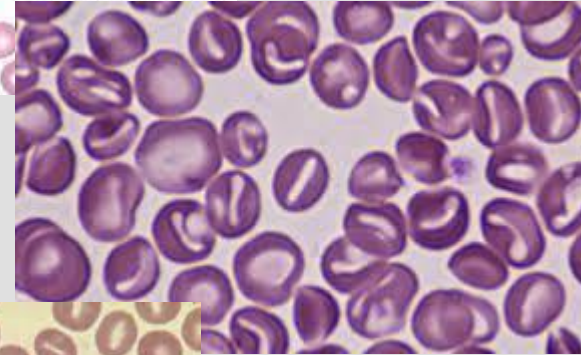
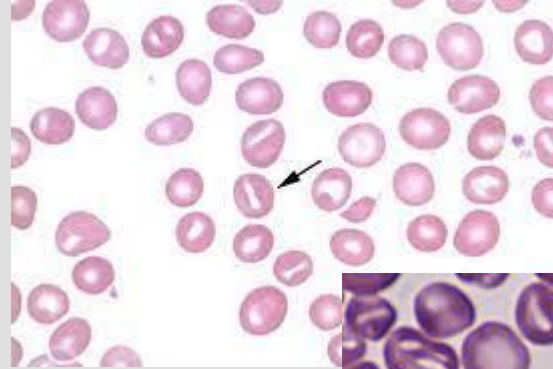
- Schistos = divided
- cyt = cell
- RBC fragment
  - Small, irregular shape
  - Jagged, with pointed ends
    - Triangular, helmet, comma shapes
  - No central pallor
- Conditions where you see this:
  - Hemolytic anemia
  - Iron deficiency anemia
  - DIC
    - Mechanical destruction of RBCs passing through fibrin clots



# Red Blood Cell Abnormalities - Shape

- **Stomatocytes**

- Stoma = mouth
  - cyt = cell
- 
- Cell is bowl-shaped in blood
    - Decreased surface area
    - Central pallor forms slit shape
    - Likely artifact unless >10% of RBCs
- 
- Conditions where you see this:
    - Hemolytic anemia
    - Liver disease
    - pH variations (more acidic blood) alter cell permeability



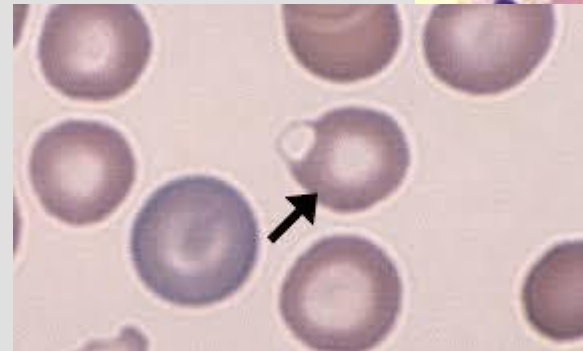
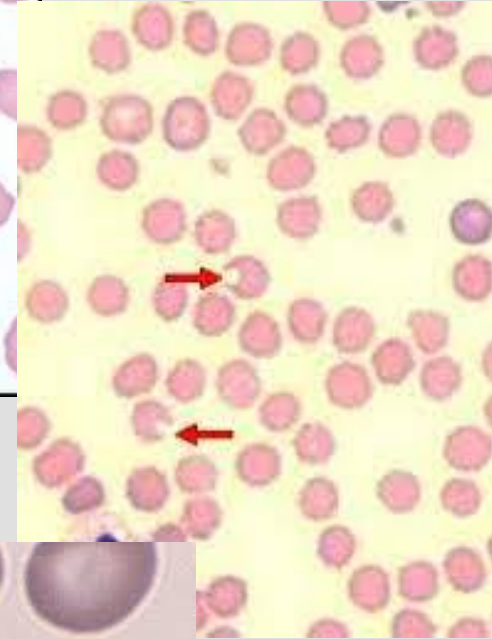
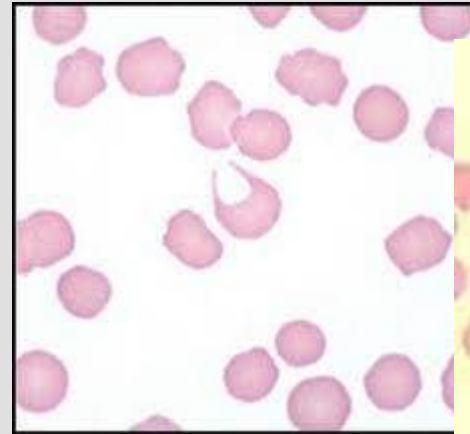


# Red Blood Cell Abnormalities - Shape

- **Keratocytes / Degmacyte**

- Kerato = horn
- Degma = bite
- cyt = cell

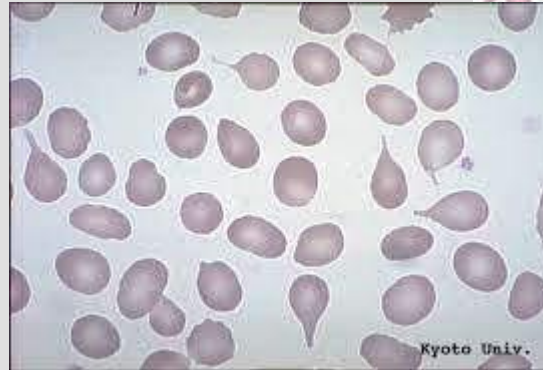
- Denatured hemoglobin forms clumps (=Heinz bodies) on the edge of the RBCs
- Cells in the spleen phagocytize these clumps, taking a “bite” out of the cell
- Fragmented RBC has one to two projections
  - Blister cell if cytoplasmic membrane connects around vacuole
  - May result in horn-like projections
  - Half-moon or helmet shape = bite cell
- Conditions where you see this:
  - Hemolytic anemia
  - Oxidative damage to hemoglobin



# Red Blood Cell Abnormalities - Shape

- **Dacrocytes**

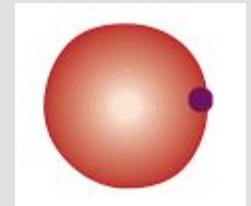
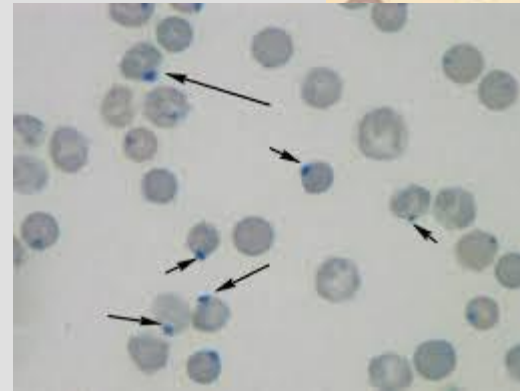
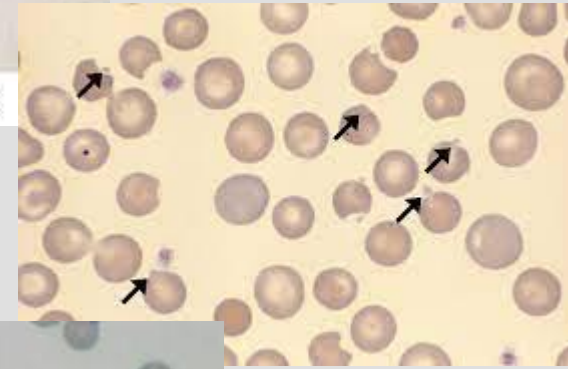
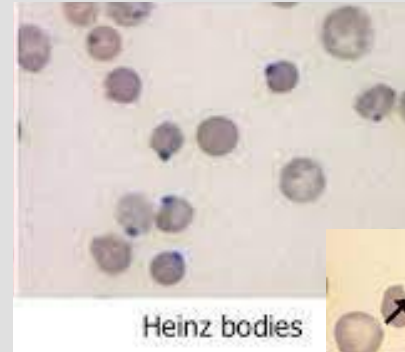
- Dakruon = teardrop
  - cyt = cell
- Teardrop shaped RBCs
  - Thought to be formed after removal of an inclusion by the spleen
    - Splenic pitting
  - Conditions where you see this:
    - Bone marrow fibrosis disorders
    - Slide artifact



# Red Blood Cell Abnormalities - Inclusions

## ● Heinz Bodies

- Denatured hemoglobin forms clumps on the edge of the RBCs
  - These clumps are Heinz bodies
- Require special staining to visualize
  - i.e. - new methylene blue
- Can appear as single lumpy projection of cell membrane
- Conditions where you see this:
  - Hemolytic anemia
  - Chronic liver disease
  - Oxidative damage to hemoglobin
  - Consumption of certain foods/chemicals or medications
    - Propylene glycol (prev. in cat food), acetaminophen, garlic, onions

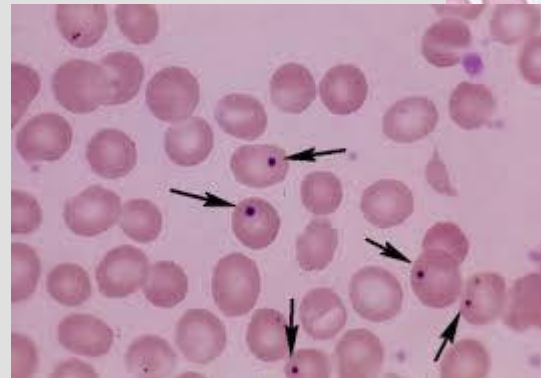
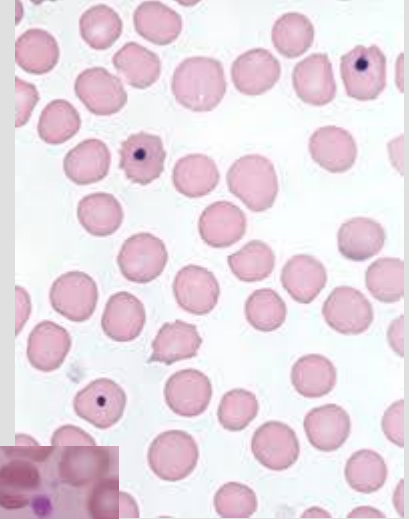
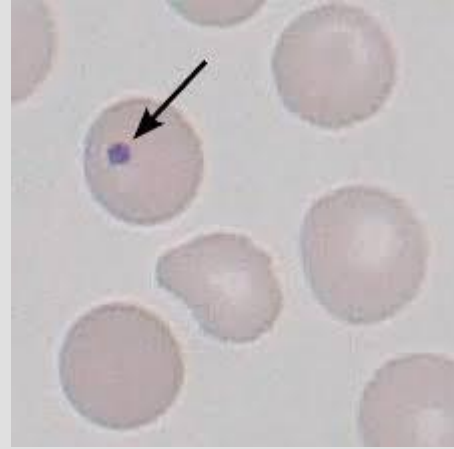




# Red Blood Cell Abnormalities - Inclusions

- **Howell-Jolly Bodies**

- Nuclear remnants (DNA clusters) in the RBCs
- Appear as purple spot within cytoplasm of RBC cells
- Conditions where you see this:
  - Splenic dysfunction
  - Post-splenectomy
  - Severe hemolytic anemia



# Red Blood Cell Abnormalities - Arrangement

- **Rouleaux**

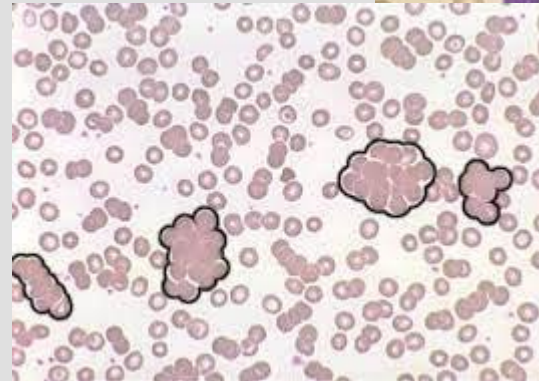
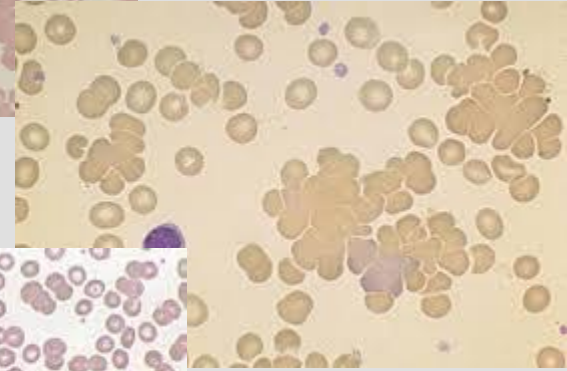
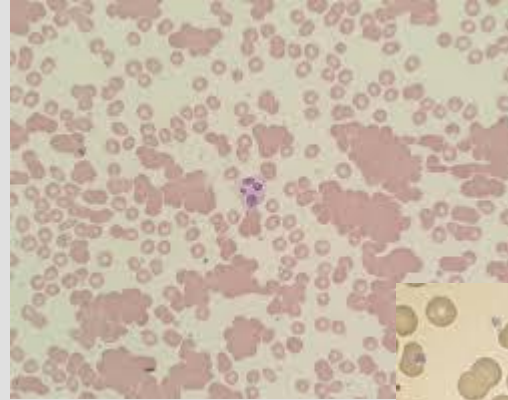
- French *roule* = roll
- Stacked aggregations of RBCs
- Occurs due to the biconcave shape of RBCs
- Some degree of rouleaux is normal in dogs and cats
- Conditions where you see this:
  - Abnormal quantities of certain proteins
  - Infections
  - Inflammatory disorders
  - Diabetes mellitus



# Red Blood Cell Abnormalities - Arrangement

- **Agglutination**

- Latin *agglutinare* = to glue together
- Clumping aggregations of RBCs
- Occurs by the formation of antibody-antigen complexes, binding RBCs together
- Conditions where you see this:
  - IMHA
  - Blood transfusion reaction
  - Slide artifact - if not in feathered edge


















# RED BLOOD CELLS

*A Spotter's Guide*

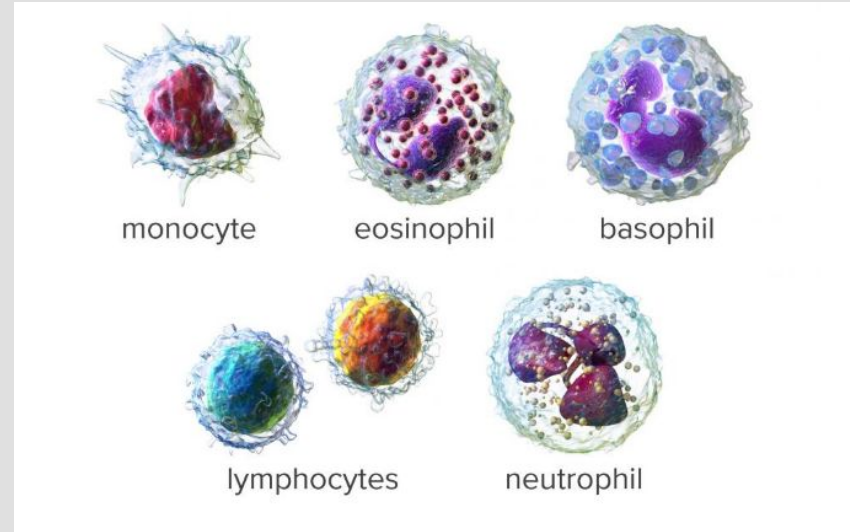


| Abnormal RBC Morphology | Cartoon Image   |
|-------------------------|---|
| What am I?              | <p>6<math>\mu</math>m</p>  <p>Normal</p> |
| What am I?              | <p>6<math>\mu</math>m</p>  <p>Normal</p> |
| What am I?              |    |
| What am I?              |    |
| What am I?              |    |
| What am I?              |    |
| What am I?              |   |

|            |  |
|------------|--|
| What am I? |    |
| What am I? |   |
| What am I? |   |
|            |  |
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| What am I? |   |
| What am I? |  |

# White Blood Cells

- **Leukocyte**
  - Leuko- means “white”
- **Morphology**
  - Varies depending on type of white blood cell
- **Origin**
  - Formed in bone marrow
  - Present in blood, lymphatic system/tissues, immune system
  - Generally a stable number of WBCs in blood unless stimulated or suppressed
- **Function**
  - Protect against infection
  - Role in inflammation
  - Role in allergic reactions
- **Conditions**
  - Leukopenia
  - Leukocytosis





# Type of White Blood Cells

## Neutrophils

- Most abundant WBC = 60-70%
- First line of defense against infection
- Mainly target bacteria and fungus, surrounding & destroying them

## Lymphocytes

- B cells, T cells, Natural killer cells = 20-30% of WBCs
- Produce antibodies, recognize & destroy infected cells and viral cells (including cancer cells)

## Monocytes

- 2-10% of WBCs
- Largest of the WBCs
- Present for chronic infections, have a longer lifespan

## Eosinophils

- 1-3% of WBCs
- Generally target larger parasites (worms)
- Modulate allergic inflammatory reactions

## Basophils

- <1% of WBCs
- Secrete heparin & histamine to defend against parasites & bacteria
- Mainly responsible for allergic reactions

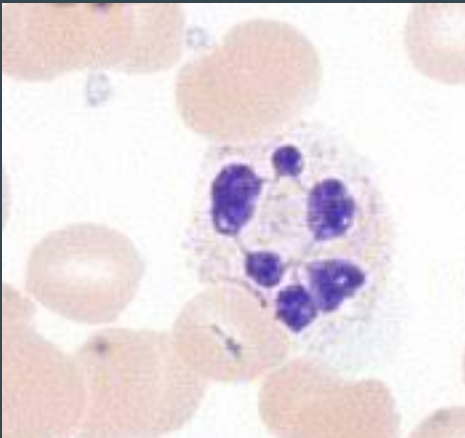
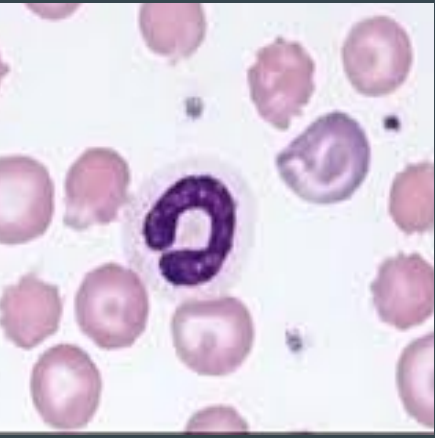
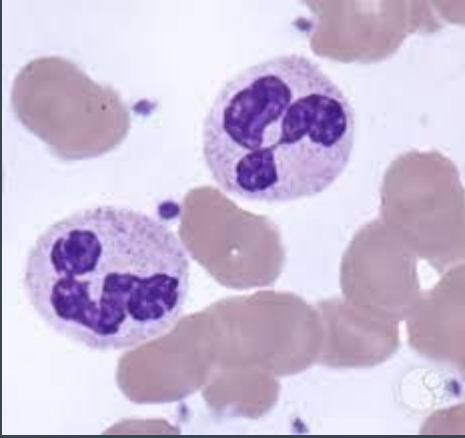
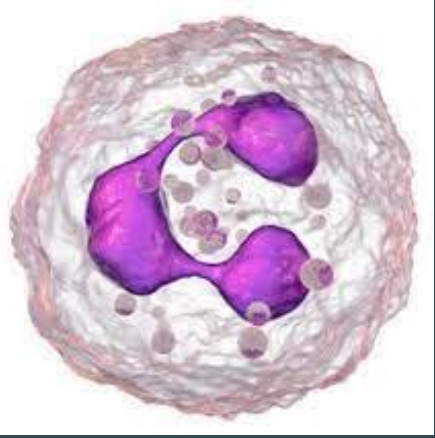
Pathogen: \*enters body\*

White blood cell:





# Neutrophils



- Originate in bone marrow
- Percentage = 60-70%
- A type of granulocyte
  - Granules are burgundy - purple staining
  - Granules contain microbicidal agents
- Multi-lobed nucleus
  - Usually 3-5 lobes
  - If more lobes, = hypersegmented
    - Means that cell has been circulating longer in blood
  - If fewer lobes, = hyposegmented
    - Means that cell is immature
    - **Bands** have no lobes
      - Segmentation occurs as they are exposed to pathogens
      - Increase in bands = “**left shift**”
- Part of innate immune system
  - Actions are immediate and non-specific (phagocytosis)
  - Cell receptors detect chemicals of infection or inflammation and migrate towards it
  - Kill and digest bacteria and fungi

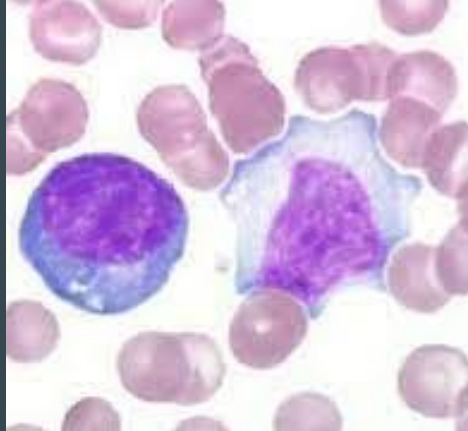
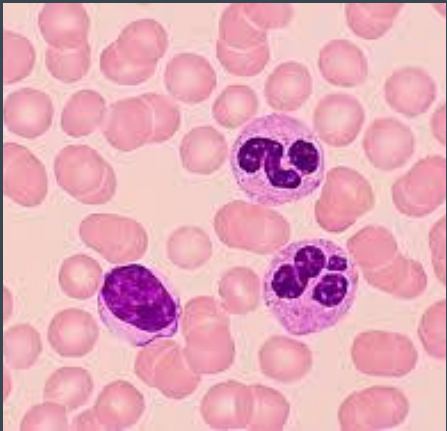
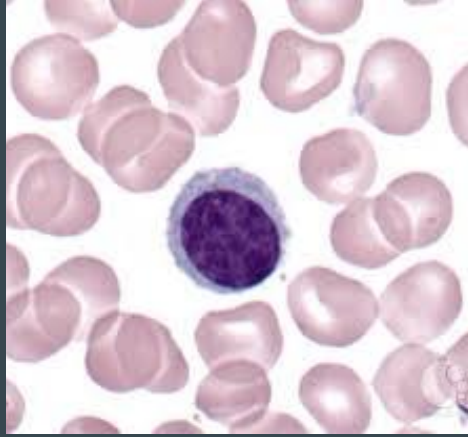
Known Pathogen: \*enters body\*

Specialized white blood cell:

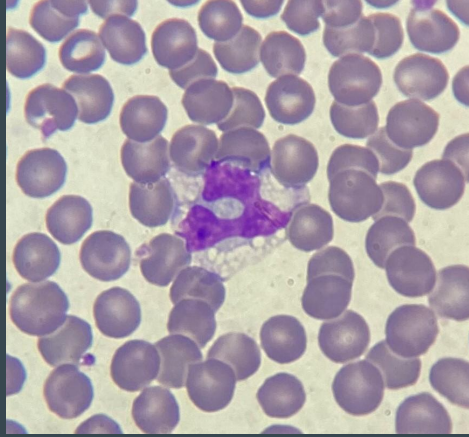
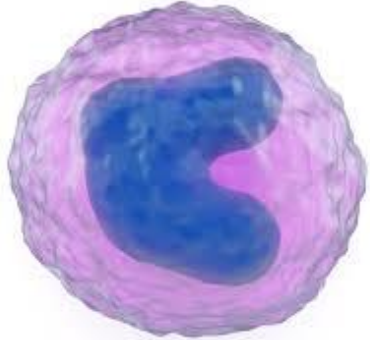


# Lymphocytes

- Originate in spleen, thymus, lymph nodes
- Percentage = 20-30%
- Develop into 3 different types
  - B cells - produce antibodies that attack and neutralize bacteria, viruses, and toxins (adaptive)
  - T cells - produce enzymes which kill infected cells (adaptive)
  - Natural Killer cells - modulate other cell functions, can identify and destroy infected/altered cells (by releasing cytotoxic granules) (innate)
- Spherical nucleus, minimal cytoplasm
  - Dense, dark staining (purple)
  - Nucleus is approximately the size of an RBC
  - Visible cytoplasm is clear (pale blue stain) and minimal
- Adaptive immunity and innate immunity
  - Specific reactions to specific antigens
  - Cells “learn” from previous encounters with foreign invaders
  - NK cells do *not* have antigen-specific receptors, are considered part of innate immune system



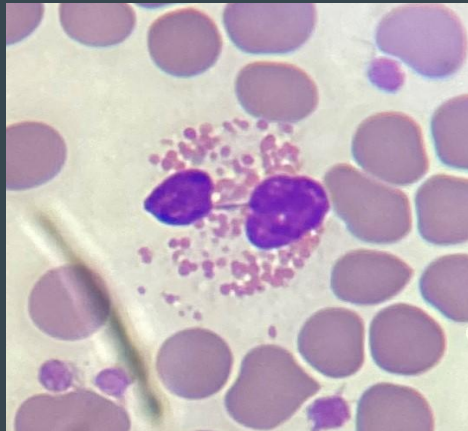
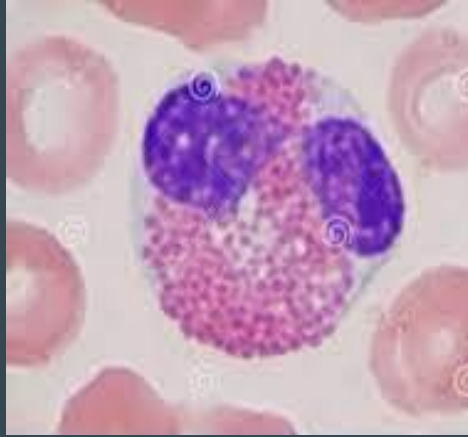
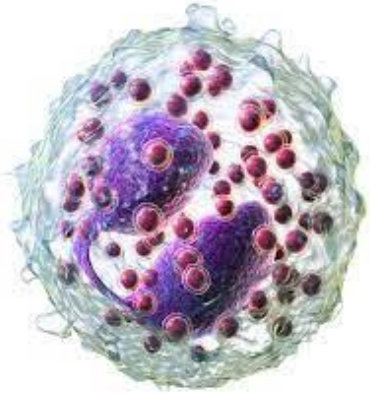
# Monocytes



- Originate in the liver, spleen, & lymph nodes
  - Circulate in blood for 1-3 days, then move into tissues
  - Large percentage stored in spleen
- Percentage = 2-10%
- Largest of the WBC
  - Once in tissues, differentiate into:
    - Macrophages - protect tissues from foreign substances
    - Dendritic cells - antigen-presenting cells
- Nucleus is pleomorphic
  - Nucleus can appear kidney-shape, unilobar, or other
  - Non-granulated cytoplasm
  - Cytoplasm - blue-grey-purple, often has vacuoles
- Innate immunity and adaptive immunity
  - Phagocytosis - uptake, digestion, and destruction of foreign material
  - Antigen presentation - microbial fragments remaining after phagocytosis are transported to the cell surface and can be used in MHC complex as antigen
  - Cytokine production - anti-inflammatory role after initial inflammatory response

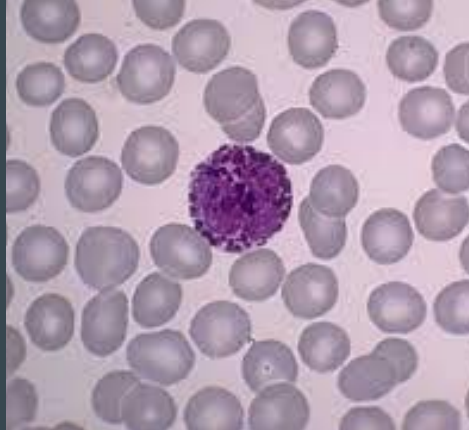
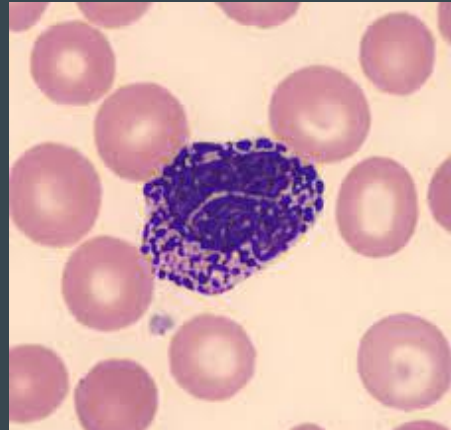
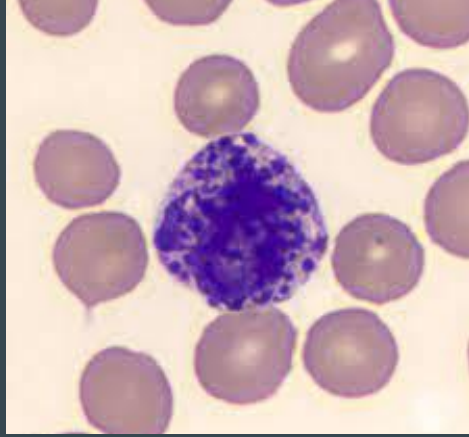


# Eosinophils



- Originate in bone marrow
    - In blood for <24 hours before migrating to tissues
    - Survive in tissues for a couple weeks
  - Percentage of WBCs = 1-3%
  - A type of granulocyte
    - Granules are bright pink -red staining
    - Granules release toxic chemicals/enzymes
      - Process = **degranulation**
      - These are toxic to parasite and host
  - Bilobed nucleus
  - Part of innate immune system
    - Multicellular parasites (worms)
    - Certain infections
    - Allergies and asthma (active in inflammatory processes)
-

# Basophils



- Originate in bone marrow
    - Short lifespan (1-2 days)
  - Percentage = 0.5-1%
  - A type of granulocyte (largest)
    - Granules are dark purple staining
    - Granules contain histamine
  - Bilobed nucleus
  - Part of innate immune system
    - Release histamine during allergic reaction or asthma attack, causing inflammation
    - Function similar to mast cells
    - “Immune surveillance”
      - Detect and destroy some early cancer cells
      - Protect against viruses, microbes, parasitic worms, various venoms
-







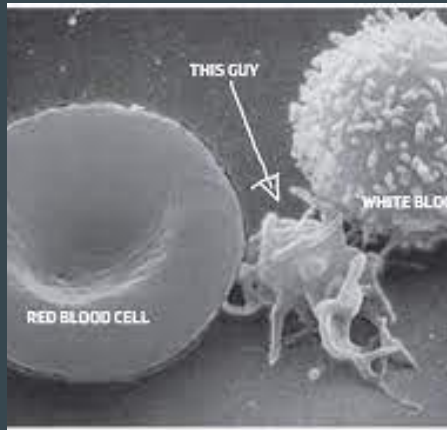
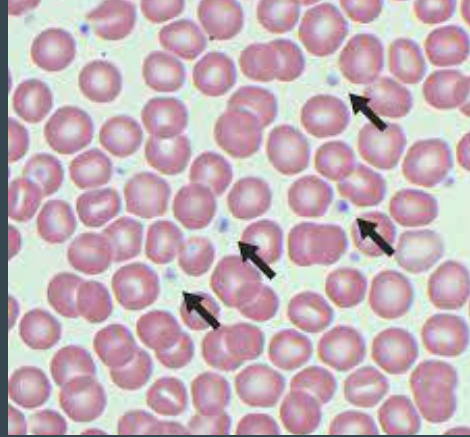
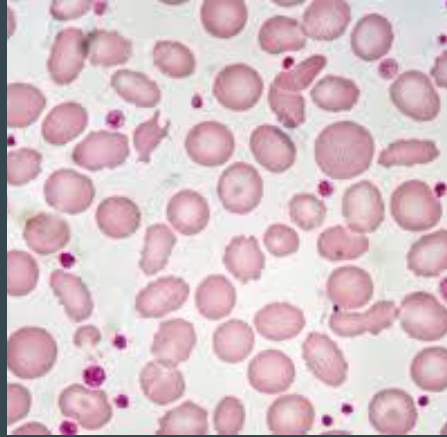
# Platelets

- **Thrombocyte**
  - Thrombo = “clot”
- **Morphology**
  - No nucleus
  - Fragments of cytoplasm
  - Circulating platelets = biconvex discs
  - Activated platelets = cell membrane projections
  - About 20% the size of RBCs
  - Purple staining
- **Origin**
  - Formed from megakaryocytes in bone marrow or lung, circulate 8-9 days in blood
- **Function**
  - Hemostasis
    - Physically plug hole in vessel
    - Activation of other clotting factors
  - Some innate and adaptive immune responses
- **Conditions**
  - Thrombocytopenia
  - Thrombocytosis



# Platelets

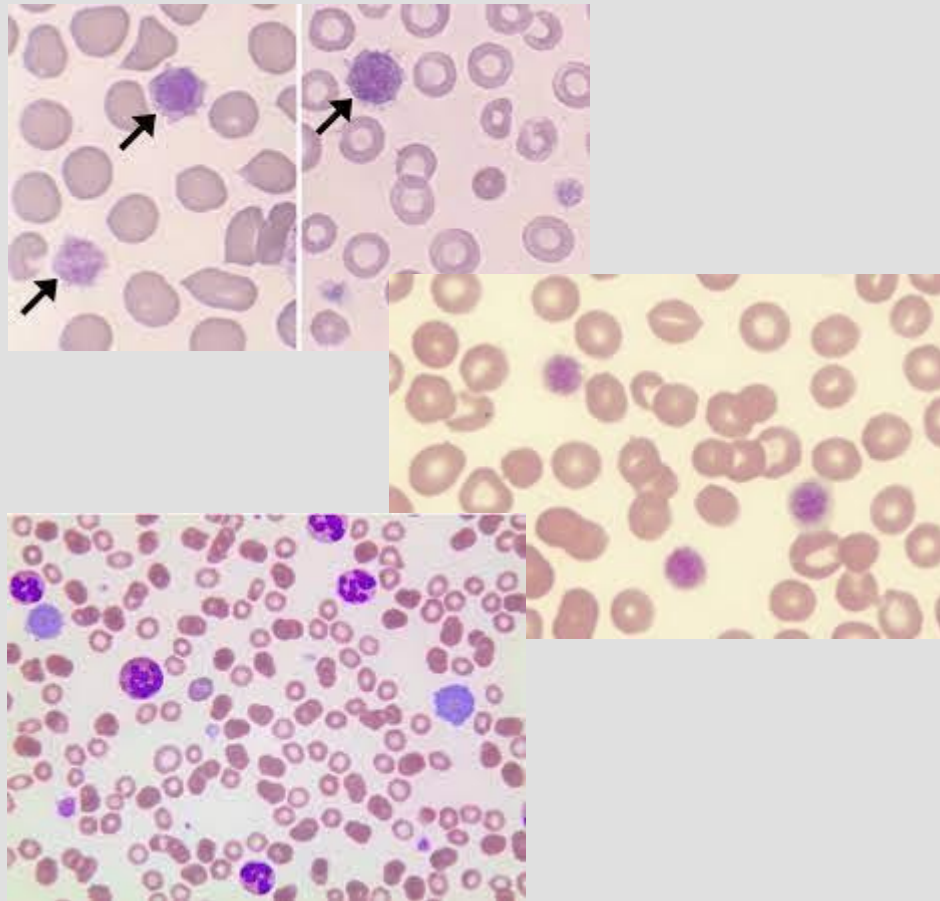
- Normal (Idexx) reference ranges are
  - Dog: 148K - 484K
  - Cat: 151K - 600K
- Abnormalities can be related to
  - Size
    - Giant platelets
  - Number present in blood
    - Thrombocytopenia
    - Manual platelet counts are performed when the number is < 200K
    - Thrombocytosis
  - Arrangement
    - Platelet clumping



# Platelet Abnormalities - Size

- **Giant platelets**

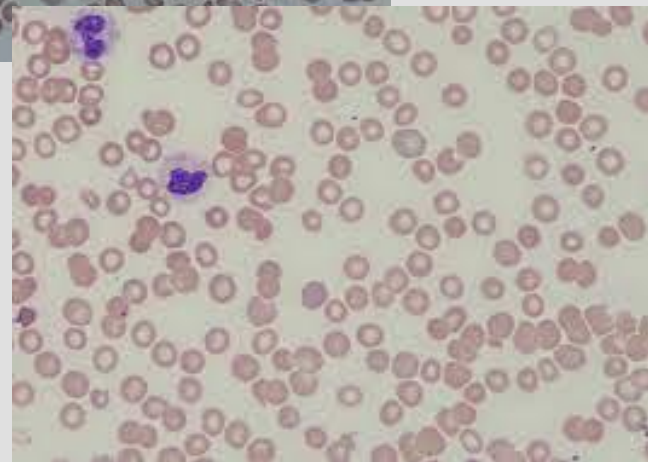
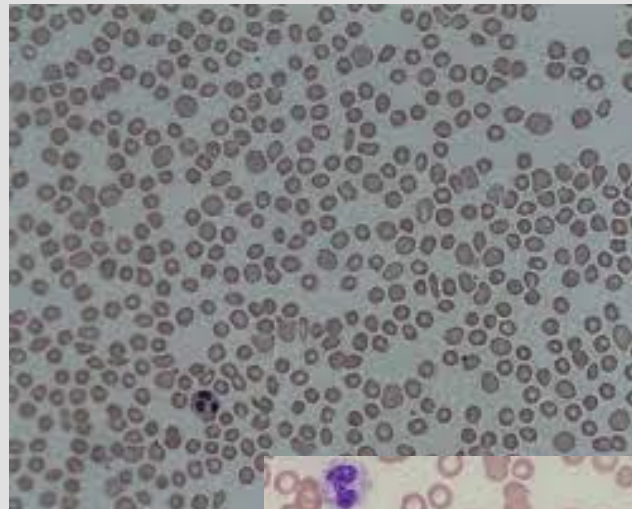
- AKA: macroplatelet
- These are often (but not always) immature platelets produced in response to a low platelet count
- May also be congenital
  - *Inherited macrothrombocytopenia*
  - Cavalier King Charles Spaniels
  - Norfolk Terriers, Cairn Terriers



# Platelet Abnormalities - Number

- **Thrombocytopenia**

- Thrombo = clot
- Cyt = cell
- Penia = deficiency
  
- Normal (Idexx) reference ranges are
  - Dog: 148K - 484K
  - Cat: 151K - 600K
  
- Conditions where we see this:
  - Acquired, usually immune-mediated
    - ITP
    - Drugs, toxins
    - Bone marrow disorders
  - Inherited
    - Gray collies - genetic, cyclical
    - Sighthounds
  - Artifact/Iatrogenic
    - Due to platelet clumping
    - Due to hemodilution

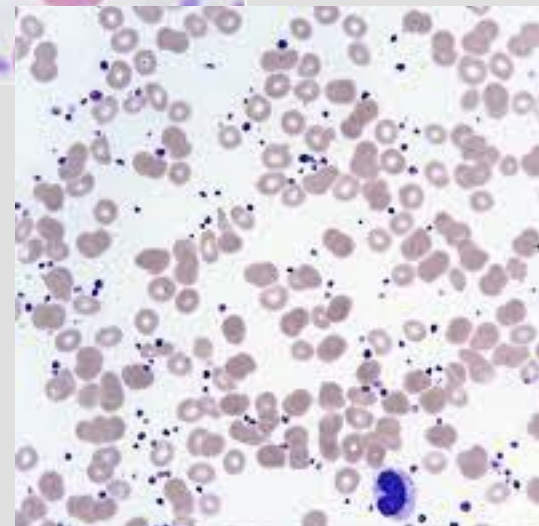
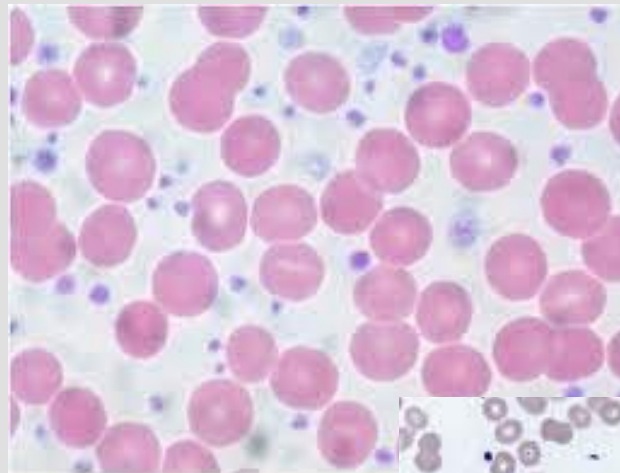




# Platelet Abnormalities - Number

- **Thrombocytosis**

- Thrombo = clot
- Cyt = cell
- Osis = condition, can mean increase
- Normal (Idexx) reference ranges are
  - Dog: 148K - 484K
  - Cat: 151K - 600K
- Conditions where we see this:
  - Response to epinephrine
    - Spleen releases stored platelets
  - As a reaction to another disease/disorder
    - Inflammation, infection
    - Blood loss, tissue damage
    - Certain drugs
    - Cushing's Disease (hyperadrenocorticism)
    - Cancer
  - Bone marrow disease
    - Increased number of megakaryocytes



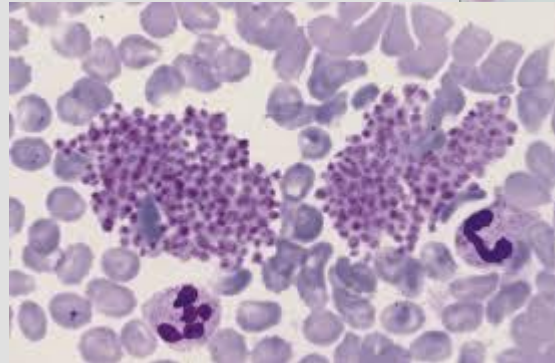
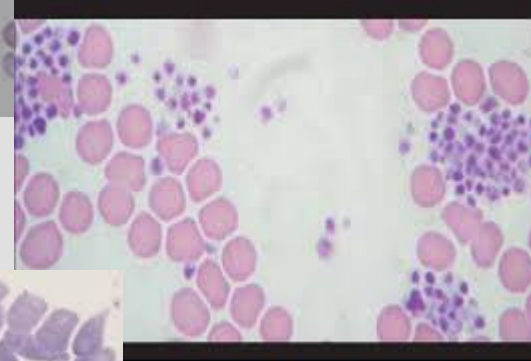
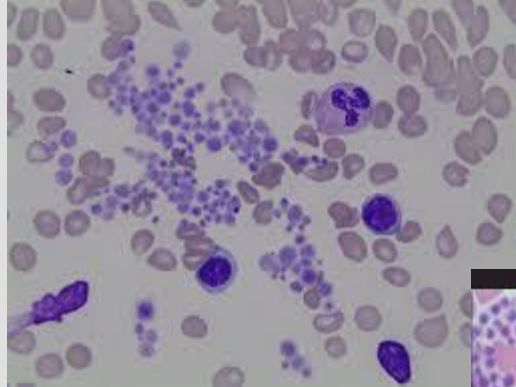
# Platelet Abnormalities - Arrangement

- **Clumping**

- Occurs when the platelets stick together in clusters
- For the most part, not clinically relevant to diagnosis
- Often causes **pseudothrombocytopenia**
  - Clumped platelets result in an artificially low platelet count on blood machines

- Frequently seen in:

- Traumatic venipuncture
  - Platelets are activated
- Reaction to EDTA (uncommon)
  - Anticoagulant in LTT causes reactionary clumping of platelets





# Review

## Red Blood Cells

- Uniform in size and shape
- Biconcave disc shape
- No nucleus when mature
- Have hemoglobin molecules which carry oxygen to tissues and return CO<sub>2</sub> to lungs

## White Blood Cells

- Neutrophils
  - Segmented nucleus
  - Granulocyte
  - Immediate, innate action
- Lymphocytes
  - Large round nucleus
  - B, T, and NK cells
  - Adaptive and innate action
- Monocytes
  - Pleomorphic nucleus
  - Macrophages & dendritic cells
  - Innate and adaptive action
- Eosinophils
  - Bilobed nucleus
  - Granulocyte, pink-staining
  - Innate action

## Platelets

- Platelets
    - Hemostasis function
    - No nucleus
    - Innate and adaptive action
- 

### WBC Continued...

- Basophils
  - Bilobed nucleus
  - Granulocyte, purple-staining
  - Innate action

# Thanks!

