# The Complete Blood Cell Count (CBC)
# CBC - Part 1: The Hemogram

## A Clinical Pathology 201 Study Module

*by*

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# The CBC



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# Special Acknowledgment

Special thanks is given to Angela Foley, MS, MT(ASCP), Department of Clinical Laboratory Sciences, LSUHSC School of Allied Health in New Orleans, LA for the use of some of her images of blood cells and for her assistance in the art of creating image files…

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# The CBC

This is the first module of a 4-part study exercise regarding the CBC. The four parts are entitled:

| | |
|---|---|
| CBC – Part 1 | The hemogram |
| CBC – Part 2 | WBC differential & blood morphology |
| CBC – Part 3 | RBC morphology & platelet estimate |
| CBC – Part 4 | Post-test |

click here to continue

# Feedback

Feedback as to the quality and usefulness of this exercise is solicited and suggestions for improvement are welcomed. Please forward your remarks by E-mail cwalte@lsuhsc.edu

or via US MAIL:

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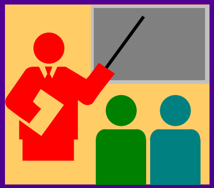
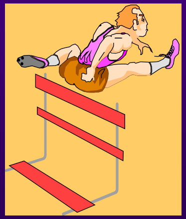
# Directions

The directions for navigating through the exer-cise are given on the next 3 pages.  They are the same as those used in the other modules of this 4-part exercise.  Click on:



to visit the directions before continuing with the exercise.

or



to bypass the directions.

# Directions, d

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The following directional icons are provided throughout the exercise for your convenience. You can click on:

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menu in the upper right corner of the page to return to the Hemogram Menu selection.

click here to continue

# Directions, d

You can click on:

in the lower right corner of the page to continue.

in the lower right corner of the Main Menu page to Quit (i.e., end the exercise).

Quit

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# Directions, d

"Hot points" (symbols, words, phrases) have been inserted on the pages as navigational tools and can be identified by their "gold" color. If it's "gold", click on it to move to the next text/data entry. Also, sounds have been added in a few places for emphasis.

Caution, failure to follow the structured order of the "hot points" may result in confusion. If you use the mouse without placing the cursor directly on the "gold hot point" or click without waiting for the "gold" to appear, you may skip over vital information.

Remember, if it's gold, click on it. Try it!

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# Special Comments

This exercise has numerous images. You may note that, when a page contains images, there may be a rather long delay before you regain control of the cursor. Please be patient. I think you will find the images are worth the wait.

**NOTE:**

Some animation and/or interactive affects may be lost if you attempt to replay a page by re-turning to the previous page and then advanc-ing to that page again.

Now, click on the gold to begin.

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# CBC – Part 1

## The Complete Blood Cell Count (CBC)

## Part 1 - The Hemogram

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# Does the CBC have clinical value ?

A CBC (complete blood count) is one of the most frequently ordered laboratory procedures. It's useful in the diagnosis and clinical management of numerous diseases and disorders, such as:

- anemias
- leukemias & other neoplasias
- infections (bacterial & viral)
- inflammatory disorders (e.g., rheumatologic)
- inherited anomalies

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menu

# What specimen is required?

A CBC (complete blood count) can be performed by automated electronic instruments or by manual methods on a whole blood specimen collected:

**by**

venipuncture - in a tube containing EDTA anticoagulant

**or**

capillary stick (e.g., finger, heel, ear) - in a vial containing a measured volume of diluent appropriate for the method used

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# What is a CBC?

A CBC is a battery of hematologic tests. The values obtained provide valuable information regarding the three types of blood cells found in peripheral blood, which are red blood cells (RBC), white blood cells (WBC), and platelets (PLT).

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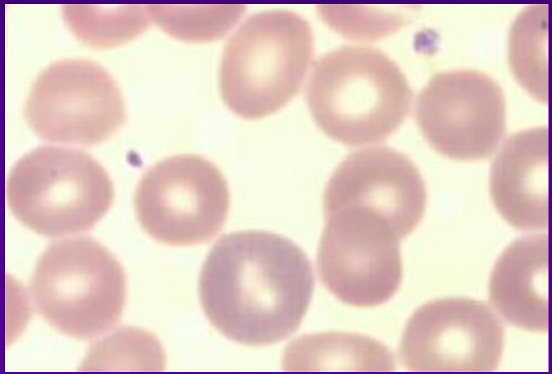
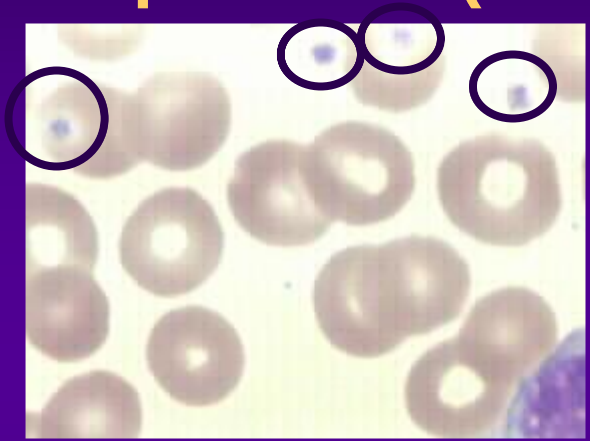
# Three types of cells in peripheral blood:

## 1. erythrocytes (RBC)

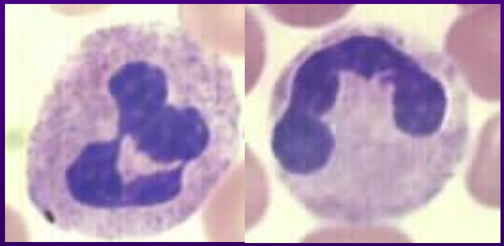


## 3. platelets (PLT)

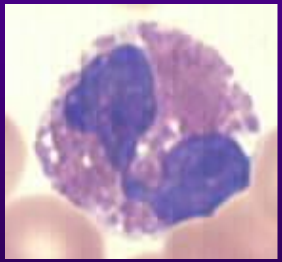


## 2. leukocytes (WBC)

**neutrophils**



**eosinophils**



**basophils**

**lymphocytes**

**monocytes**

# What information is provided by a CBC?

Basically, the CBC provides information regarding the:

- number of red cells, white cells, and platelets in circulating peripheral blood
- frequency distribution of white blood cells
- morphologic features of the blood cells
- hemoglobin content of red blood cells
- relationship of red blood cells to total blood volume and hemoglobin concentration

# What are the components of a CBC?

In most laboratories, due to advanced technologies now available, an automated CBC is performed on a multi-channel instrument employing a variety of techniques. It usually includes a:

1. Hemogram
2. Differential WBC count
3. General description of blood cell morphology (WBC, RBC, and PLT)
4. Platelet estimate

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# HEMOGRAM

hemogram menu

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# HEMOGRAM MENU

- Introduction
- Total WBC Count
- Corrected WBC Count
- Total RBC Count
- Hemoglobin
- Hematocrit
- Erythrocyte (RBC) Indices
- Red Cell Distribution Width (RDW)
- Platelet Count
- Mean platelet volume

STOP

Quit

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menu

# Introduction

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# What is a hemogram?

The hemogram components of a CBC are hematologic assays/procedures that provide useful information regarding the red blood cells (RBC), white blood cells (WBC), and platelets (PLT).

Automated electronic instruments are able to:

- enumerate the number of each of the three blood cell types
- differentiate normal from abnormal cells
- provide a variety of information related to each

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# What are the components of a hemogram?

**WBC** - total number of white blood cells per μL of blood (SI units = per L)

**RBC** - total number of red blood cells per μL of blood (SI units = per L)

**HGB** - average number of grams of hemoglobin in red blood cells per dL of blood (SI units = per L)

**HCT** - hematocrit or % of packed red blood cells per unit of blood

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# Are the RBC indices included in a hemogram?

The RBC indices is usually provided as part of an automated hemogram and includes.

**MCV (mean corpuscular volume)**

average size ($\mu^3$) of the red blood cells

**MCH (mean corpuscular hemoglobin)**

average hemoglobin content ($\mu\mu$g) in individ-ual red blood cells

**MCHC (mean corpuscular hemoglobin concen-tration)**

average hemoglobin concentration (%) per unit of packed red blood cells

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# What additional components are frequently included in a hemogram?

Depending upon the laboratory and available instrumentation, the hemogram may also include:

**PLT** - total number of platelets per μL of blood (SI units = per L)

**MPV (mean platelet volume)** - average size ($\mu^3$) of individual platelets

**RDW (red cell distribution width)** - an index of the variation in size of the red blood cells

Each parameter of the hemogram will be discussed later.

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# Are the parameters of automated hemo-grams direct or indirect measurements?

Hemogram data obtained via an automated multi-channel instrument are obtained by one of two methods.

Direct counts/measurements

or

Indirect calculated measurements

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# Which components are:

Direct counts or measurements?

WBC
RBC
HGB
PLT
MCV

Indirect calculated measurement based on direct measurements of other parameters?

HCT
MPV
RDW

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# Are the RBC indices measured directly or indirectly?

A combination of direct and indirect measurements are used:

**MCV** (direct measurement of RBC volumes or sizes)

**MCH** (indirect calculation based on direct measurements for HGB and RBC)

**MCHC** (indirect calculation based on direct measurements for HGB and HCT)

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# Why do we want to know whether measurements are made directly or indirectly ?

In some instances, interference factors can affect the validity of measurements.

When evaluating the validity of direct measurements, interference factors affecting only the parameter measured must be considered.

When evaluating the validity of indirect measurements, interference factors affecting each parameter used to calculate the indirect measurement must be considered.

Interference factors are discussed briefly at the end of this exercise.

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# How do you know if patient values are normal or abnormal?

A reference range of values for adults is provided for each parameter of the CBC. These values, which are generally considered to be normal, may be gender dependent for some parameters.

CBC patient values printed out by the multichannel instruments are usually flagged when higher or lower than the reference values.

Be aware that the reference ranges for children are different from adults and may vary according to age group (e.g., newborn, infants 10-17 months, child 1.5 - 4 years) .

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# Are reference values the same for every laboratory?

**Always refer to the reference ranges established by the laboratory performing the CBC before evaluating patient results. Variation among laboratories may be seen due to different methodologies and/or patient populations.**

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# Examples of reference ranges (may vary among laboratories):

| Parameter | Units | Range |
|---|---|---|
| WBC | x $10^3/\mu L$ | 4.5 - 11.0 |
| RBC | x $10^6/\mu L$ | m = 4.60 - 6.20<br>f = 4.20 - 5.40 |
| HGB | g/dL | m = 13.5 - 18.0<br>f = 12.0 - 16.0 |
| HCT | % | m = 40.0 - 54.0<br>f = 38.0 - 47.0 |

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# Reference Ranges (d)

| Parameter | Units | Range |
|---|---|---|
| MCV | $\mu^3$ | 80 - 96 |
| MCH | µµg | 26 - 34* |
| MCHC | % | 31 - 37* |
| PLT | x $10^3/\mu L$ | 150 - 450 |
| MPV | fL | 6.5 - 12.0 |
| RDW | | 11.6 - 14.6 |

* CHNO ranges

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# End of Introduction

This concludes the Introduction to the Hemogram Section. Select one of the following:

Go to Total WBC Count, the next section, to continue with the exercise as designed.

OR

Return to the Hemogram Menu and make an alternate selection.

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# Total WBC Count

# What is a total WBC count ?

A total white blood cell count is the number of leukocytes present per unit of peripheral blood (e.g., 6,000/μL).

WBC normally present in peripheral blood and included in the total WBC count are mature forms of neutrophils, eosinophils, and basophils; a few band neutrophils (about 0-5%); lymphocytes (mature and occasional atypical forms), and monocytes.

view WBCs or continue

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menu

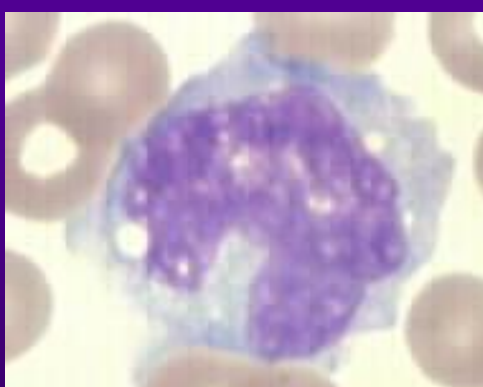
# WBC in Normal Blood (Adults):



neutrophils

eosinophil

basophil



monocyte

lymphocyte

*ATL (few)

*atypical lymphocyte

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# In disease states, what other leukocytes may be included in the total WBC count ?

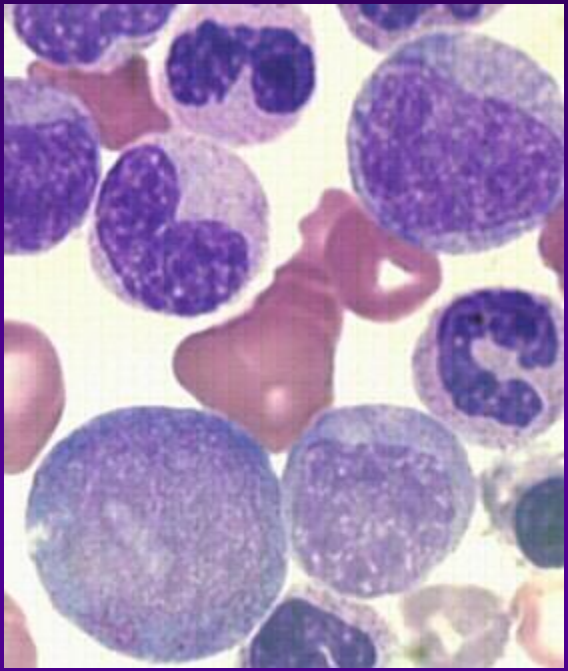
When present in disease states, in addition to leukocytes normally circulating in peripheral blood, the total WBC count may also include:

- Immature leukocytes
- Leukoctyes with abnormal morphologic alterations (which may be acquired or inherited)
- Leukocytes associated with neoplastic disorders (e.g., leukemia)

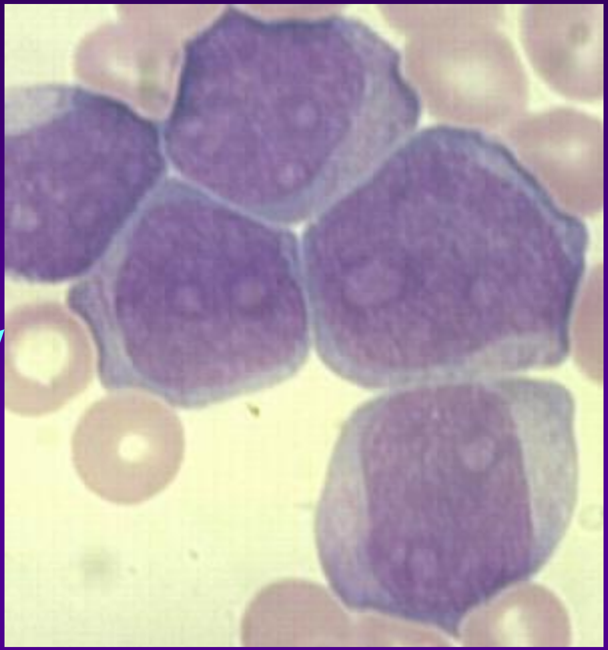
view WBCs or continue

menu

# Examples of immature WBC:

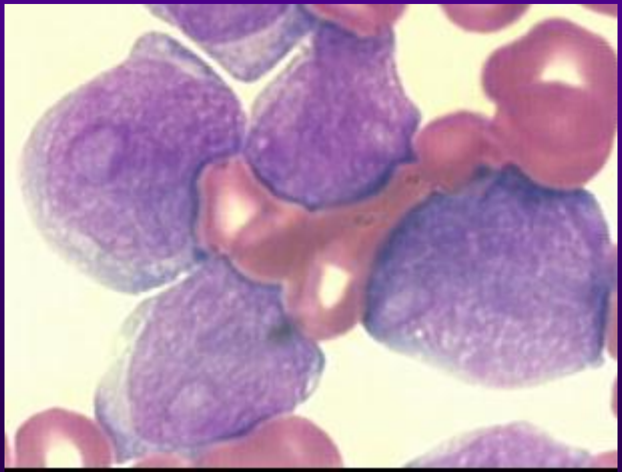


granulocytes
(various stages)

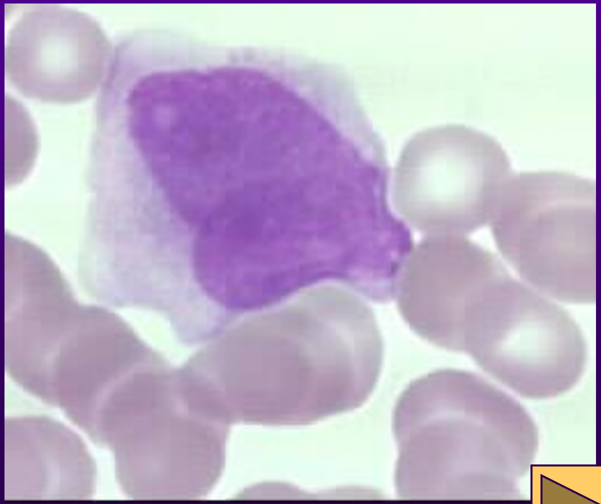


myeloblasts

lymphoblasts



monoblasts



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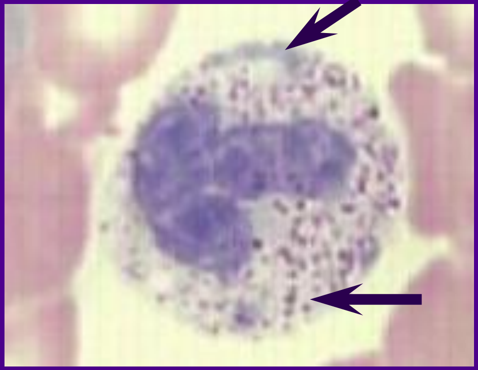
# Examples of WBC with acquired non-neoplastic abnormal alterations:

**neutrophils**

**lymphocytes**

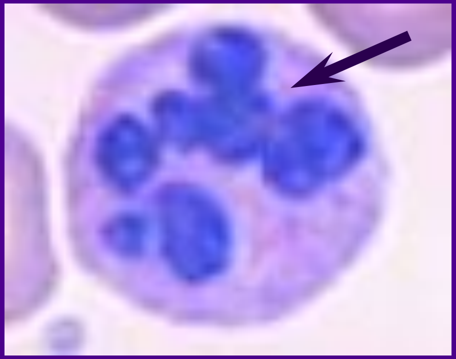
in bacterial infections



with
Dohle bodies
and/or
toxic granulation

&

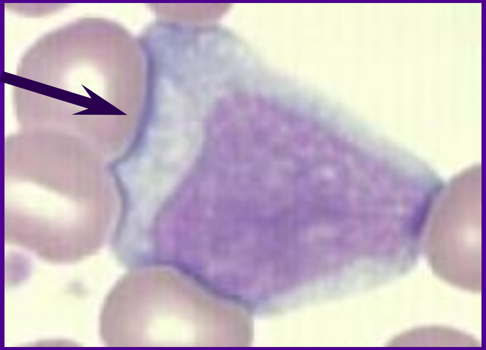
in megaloblastic anemias



with nuclear hypersegmen-tation (> 5 lobes)

&

in viral infections



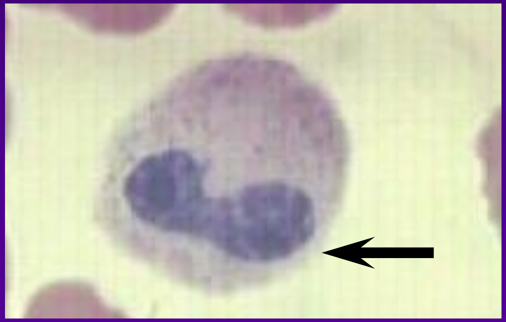
with reactive (atypical) changes

# Examples of WBC with inherited non-neoplastic abnormal alterations:



menu

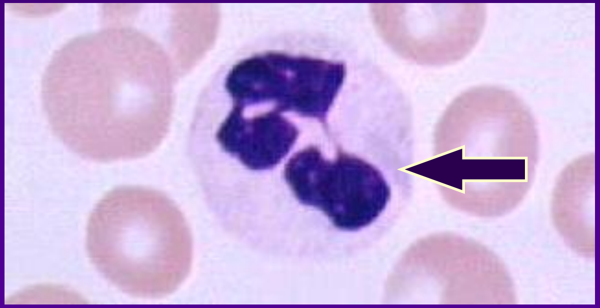
## Pelger-Huet Anomaly



hyposegmented neutrophils

&

## May-Hegglin Anomaly



neutrophils w/ inclusions

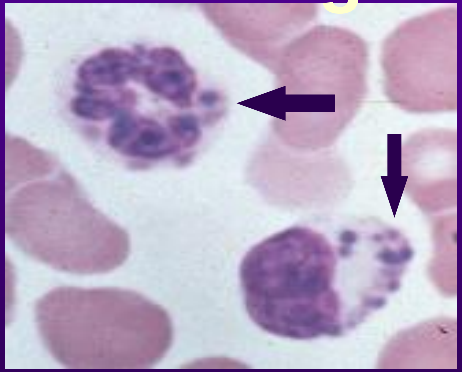
## Alder-Reilly Anomaly

&

neutrophils w/ abnormal granules

## Chediak-Higashi Syndrome

&



neutrophils and lymphocytes w/ inclusions

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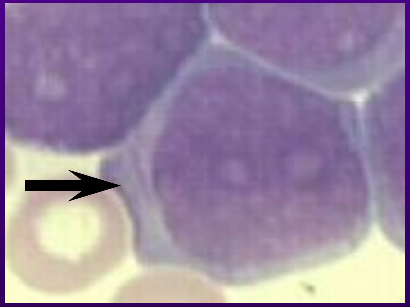
# Examples of neoplastic WBC alterations:

## hairy cell leukemia

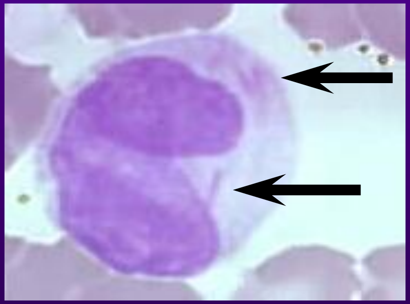
hairy cell lymphocytes

&

## acute myelocytic leukemias



myeloblasts



w/ Auer rod(s)

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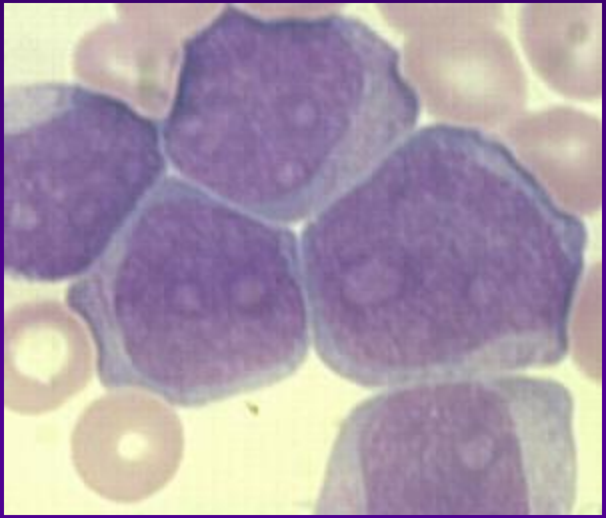
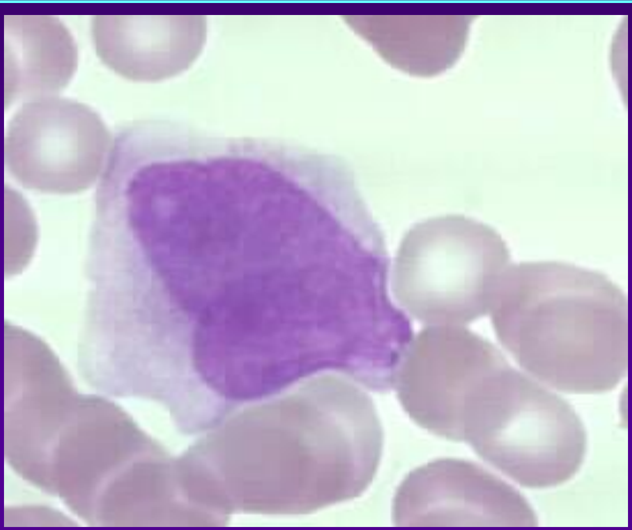
# Examples of WBC in acute leukemia:

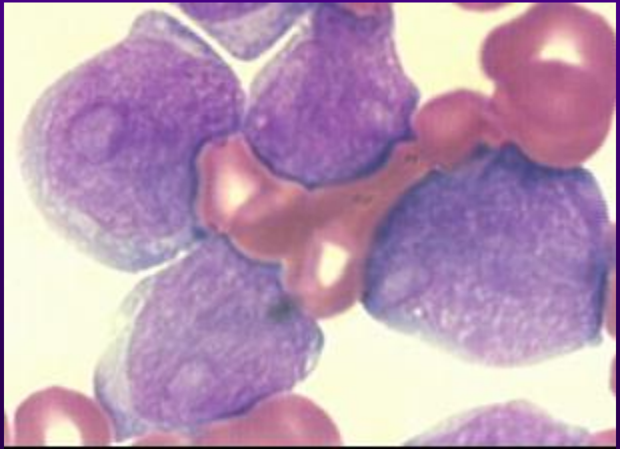
AML -myeloblasts



AMML - monoblasts



ALL - lymphoblasts



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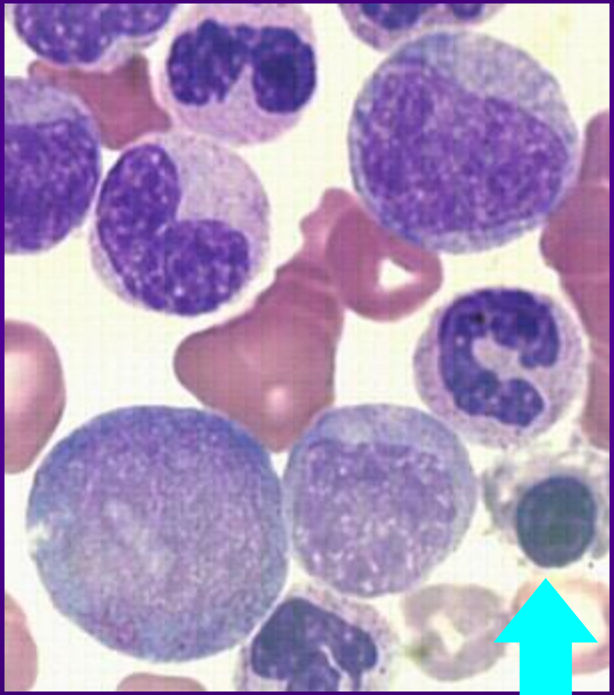
# Examples of WBC in chronic leukemia:

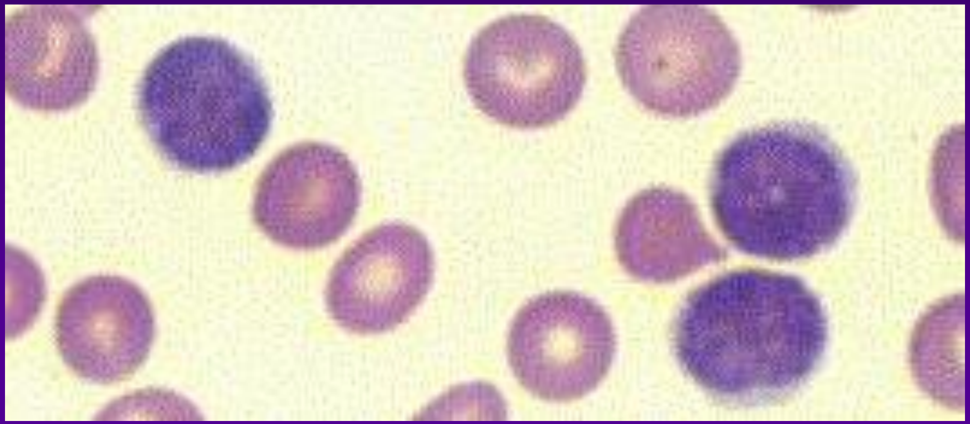
CML - granulocytes (various stages)



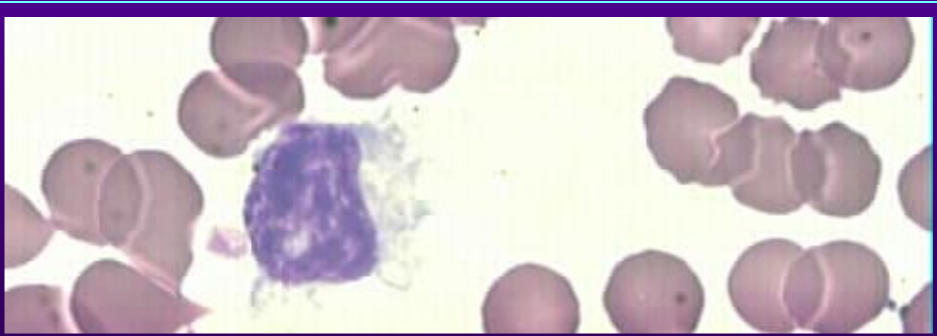
caution

That's a nucleated RBC… more about NRBC later

CLL - mature lymphocytes



CLL - hairy cell lymphocytes



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# Are leukocytes the only cells included in the total WBC count?

Remember, all nucleated cells are included in the total WBC count.  If present, nucleated red blood cells (e.g., in newborns and some disease states) will also be counted.

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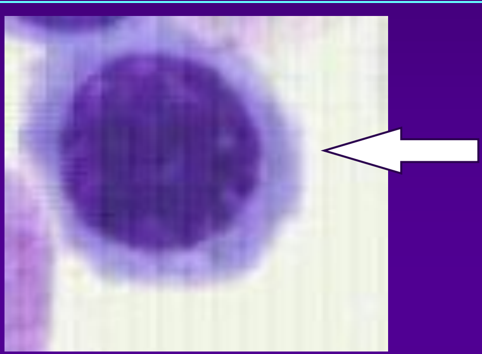
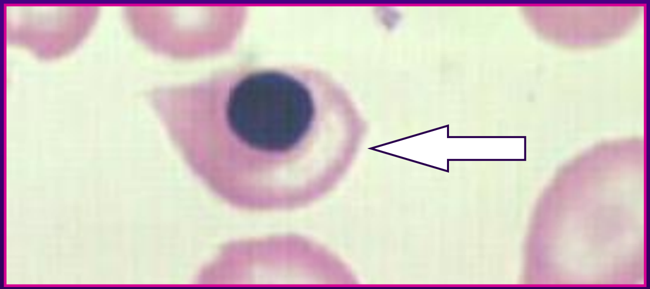
# Examples of nucleated RBC in various stages of maturation:

proerythroblast

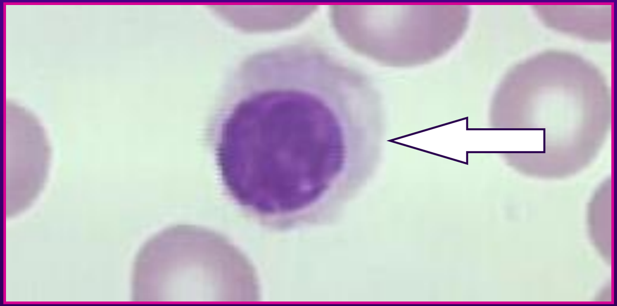
basophilic erythroblast



orthochromatophilic erythroblast



polychromatophilic erythroblast



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# If NRBC are included in the count, how can the number of WBC be determined?

When nucleated red blood cells are included, the total WBC count must be corrected for their presence.  (Refer to the Corrected Total WBC Count Section on the Menu.)

A corrected total WBC count is determined manually and added to the report as a “corrected WBC”.

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# Of what clinical importance are WBC counts?

WBC counts may be abnormal in disease states. WBC counts are characteristically:

d e c r e a s e d

- some viral infections
- acute leukemias (some cases/phases)
- during chemotherapy

&

i n c r e a s e d

- infections (bacterial and some viral)
- leukemoid reactions
- leukemias
- myeloproliferative disorders

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## Does the total WBC count differentiate WBC as to cell line?

No, the total WBC count is the total number of all nucleated cells. In the case of abnormal total WBC counts, a differential WBC count must be performed before it can be determined which cell line is decreased or increased.

It is also important to determine whether the increase/decrease is a relative percent or absolute number, which is discussed in the Differential WBC section presented later.

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# End of Total WBC Count

**This concludes the Total WBC Count Section. Select one of the following:**

**Go to Corrected WBC Count, the next section, to continue with the exercise as designed.**

**OR**

**Return to the Hemogram Menu and make an alternate selection.**

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# Corrected WBC Count (for presence of NRBC)

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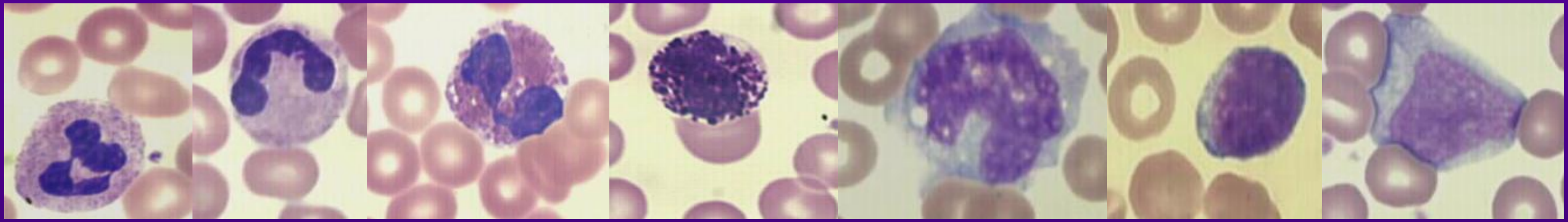
# What is the procedure for correcting the total WBC count for NRBC ?

**While performing a differential WBC count on a Wright's or Wright's-Giemsa stained peripheral blood smear:**

**Count at least 100 WBC, e.g.,**



**PMNs bands eosinophils basophils monocytes lymphocytes & ATL**

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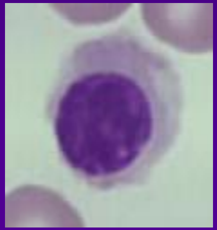
## …procedure for correcting the total WBC count for NRBC continued…

**While counting the WBC, record the number of NRBC observed during the count, e.g., the number of…**


proerythroblast


basophilic erythroblast


polychromatophilic erythroblast


orthrochromatophilic erythroblast

**Then apply the following formula…**

$$\text{True Total WBC} = \frac{\text{Uncorrected total WBC} \times 100}{{}^{*}100 + \text{number of NRBC}}$$

* i.e., 100 is the number of WBC counted

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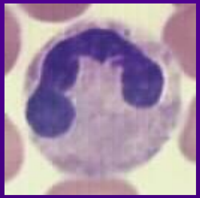
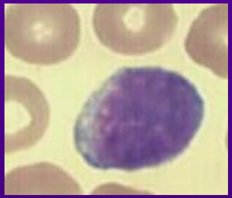
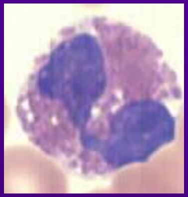
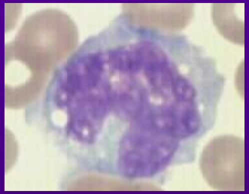
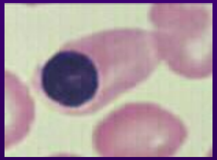
# An example situation that requires a corrected (or true) total WBC count:

**Patient: a 26-year-old female**

- ¤ total uncorrected WBC count = 10,000/µL
- ¤ 100 WBC are counted on a Wright's stained peripheral blood smear…(for example)

WBC ⟶     

65 + 5 + 25 + 3 + 2 = 100

- ¤ 25 NRBC  { are observed while counting the 100 WBC

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menu

# The corrected (or true) WBC count is calculated:

Uncorrected total WBC count = **10,000/µL**

NRBC = **25/100 WBC**

(i.e., 25 NRBC were noted per 100 WBC counted on a stained peripheral blood smear)

## True/Corrected WBC Count

$$\frac{10{,}000 \times 100}{100 + 25} = \frac{1{,}000{,}000}{125} = 8{,}000/\mu L$$

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# What are the effects of NRBC on the total WBC count?

menu

The effects of NRBC on the total WBC count depend upon the number of NRBC present and the total uncorrected WBC count. For example, if the uncorrected WBC is low:

| Before Correction No. WBC | Before Correction Interpretation | NRBC /100 WBC | After Correction No. WBC | After Correction Interpretation |
|---|---|---|---|---|
| 5,000 | Normal | 1 | 4,950 | Normal |
| 5,000 | Normal | 10 | 4,545 | Marginally decreased |
| 5,000 | Normal | 20 | 4,160 | Decreased |

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menu

# What are the effects of NRBC on the total WBC count…

**If the total <u>un</u>corrected WBC count is high? For example:**

| Before Correction No. WBC | Before Correction Interpretation | NRBC /100 WBC | After Correction No. WBC | After Correction Interpretation |
|---|---|---|---|---|
| 12,000 | Increased | 1 | 11,880 | Increased |
| 12,000 | Increased | 10 | 10,900 | Marginally increased |
| 12,000 | Increased | 20 | 10,000 | Normal |

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menu

# What effects do large numbers of NRBC have on WBC counts?

For example:

| Before Correction No. WBC | Before Correction Interpretation | NRBC /100 WBC | After Correction No. WBC | After Correction Interpretation |
|---|---|---|---|---|
| 5,000 | Normal | 40 | 3,560 | Decreased |
| 12,000 | Increased | 40 | 8,570 | Normal |
| 50,000 | Markedly High | 400* | 10,000 | Normal |

* not an uncommon finding in severe anemias

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# End of Corrected WBC Count

**This concludes the Corrected WBC Section. Select one of the following:**

**Go to Total RBC Count, the next section, to continue with the exercise as designed.**

**OR**

**Return to the Hemogram Menu and make an alternate selection.**

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menu

# Total RBC Count

# What is the total RBC count?

The total red blood cell count is the number of erythrocytes present per unit of peripheral blood (e.g., /μL).

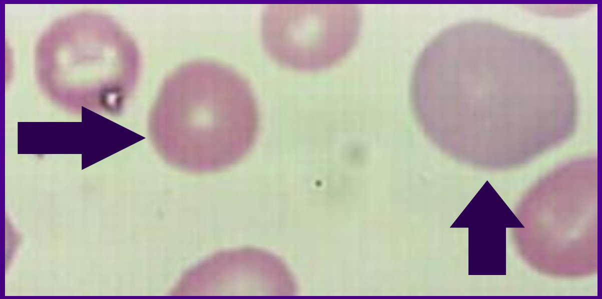
However, with the exception of platelets, all cells (i.e., red blood cells and white blood cells) are actually counted. In the case of healthy adults, the inclusion of the white blood cells is not clinically significant.

menu

# What red blood cells are included in a *normal* total RBC count?

**With the exception of newborns, the RBC count on normal peripheral blood is essentially a reflection of the number of erythrocytes, i.e..**

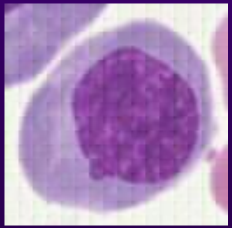
primarily mature erythrocytes



&

0.5 - 1.5% polychromatophilic erythrocytes

**Erythroblasts (nucleated RBC):**



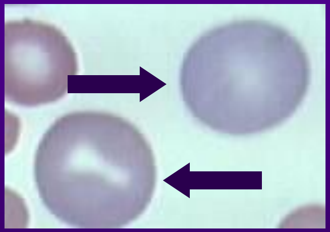
are not seen in normal blood.

# Which cells are classified as erythrocytes?

Erythrocytes are red blood cell forms without a nucleus which includes:

mature erythrocytes

&



polychromatophilic erythrocytes

menu

# How do erythroblasts differ from erythrocytes?

**Erythroblasts are red blood cell forms with a nucleus (for example):**

**orthochromatophilic erythroblast**

**polychromatophilic erythroblast**

**basophilic erythroblast**

**proerythroblast**

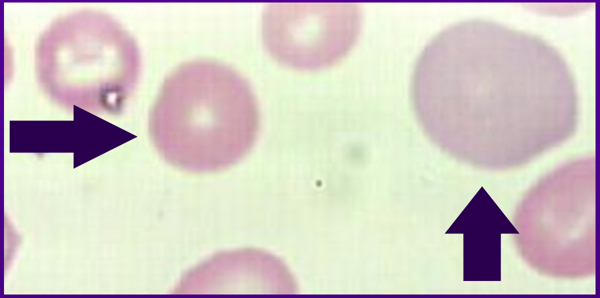
menu

# Are NRBC ever seen in normal peripheral blood?

Erythroblasts (NRBC) are not seen in normal adult blood but may be seen in the peripheral blood of newborns and in adults in disease.  However, the RBC count will reflect the number of all RBC, i.e.:

(anucleated RBC):

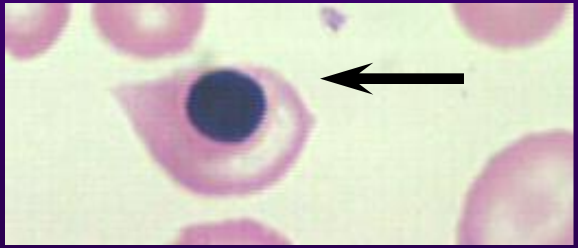
mature erythrocytes



& polychromatophilic erythrocytes

&, if present, nucleated RBC

erythroblasts



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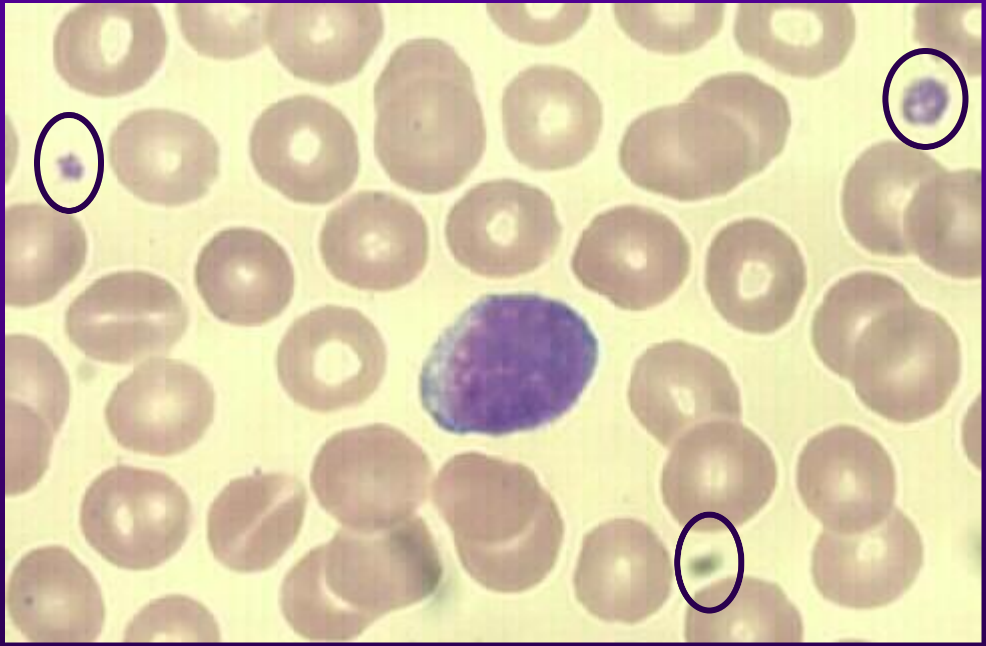
menu

# Why are other cells included in the total RBC count?

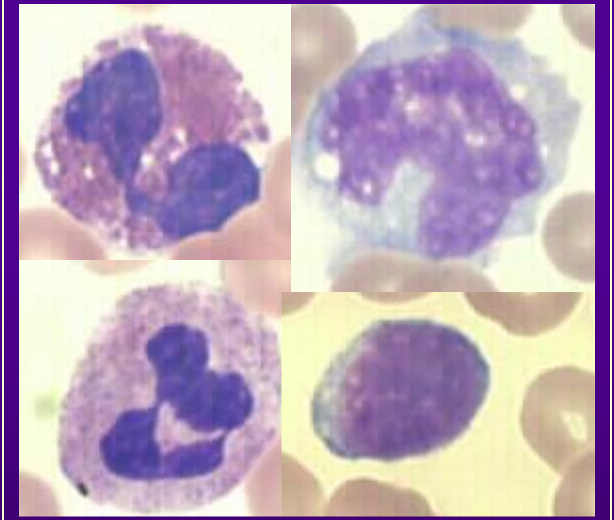
Although intended to reflect only the number of erythrocytes (red blood cells) in circulation, the RBC count in reality includes all blood cells except normal platelets, which are excluded because of their small size.



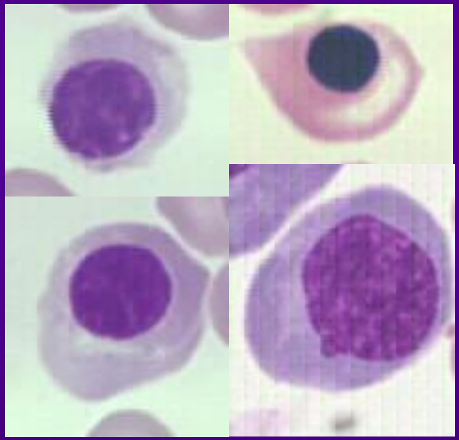
# Why are other cells included in the total RBC count?

Neither size criteria nor lysing techniques can be used to exclude…

white blood cells



erythroid precursors



giant platelets & clumps

from the RBC count because to do so would also cause the red blood cells to be excluded.

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## What affect does the inclusion of other cells have on the total RBC count?

**Total WBC counts that are normal or only slightly increased will have little or no affect on the total RBC. WBC are reported in thousands/µL and RBC are reported in millions/µL.**

**For example: RBC = 4,520,000 ($4.52 \times 10^6$)/µL**
**WBC = 8,000 ($8.0 \times 10^3$)/µL**

**If the RBC is corrected for the presence of the WBC, then RBC = 4,512,000 ($4.51 \times 10^6$)/µL. The difference is *clinically insignificant*.**

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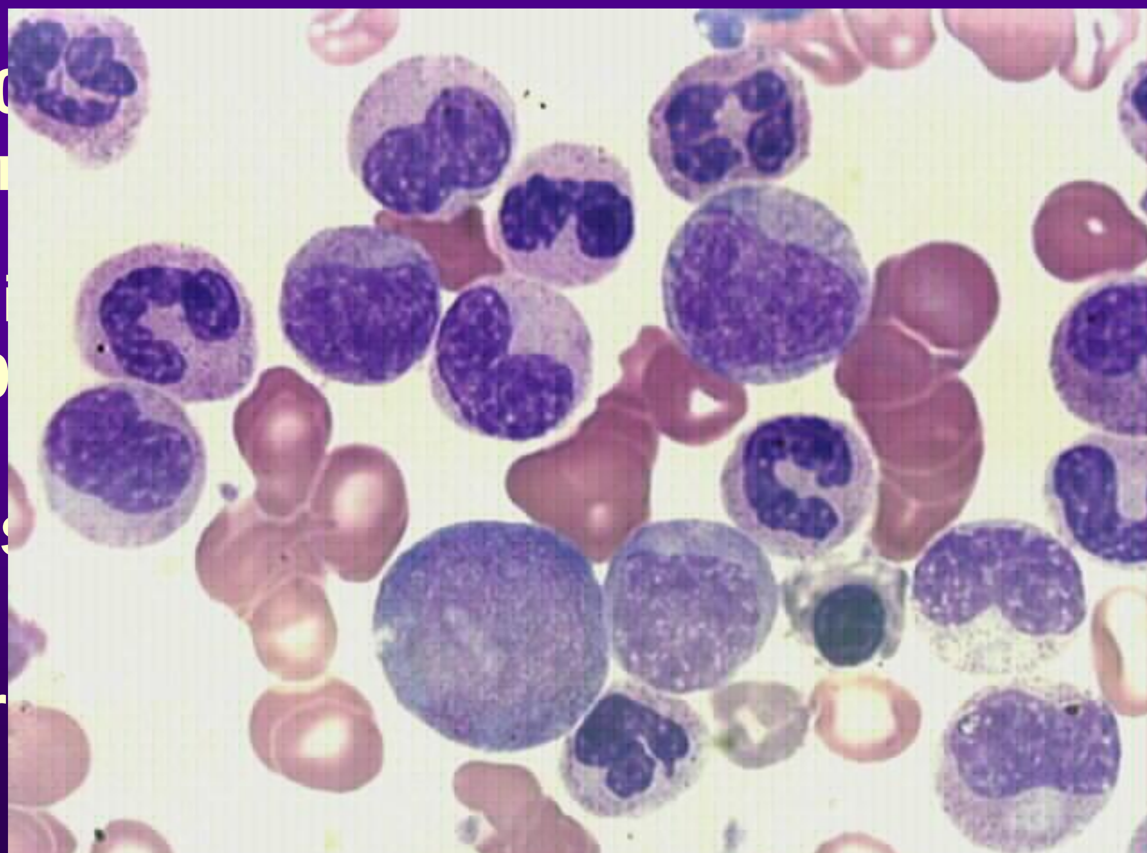
menu

# Effect of increased WBC?

In disease states characterized by large numbers of WBC, it is important to remember that they too will be included in the RBC count. For example…



RBC = 4,00
CML patie ... .

If the RBC i ... BC, then
RBC = 4,00

In this ca ... be less
than that ... may
have mor

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menu

# Effect of NRBC in disease states?

In disease states characterized by large numbers of NRBC (e.g., thalassemia), it is important to remember that they too will be included in the RBC count.

For examp

NRBC = 40 major)
RBC = 3,00
Total WBC

If the RBC
uncorrecte n…
RBC = 3,00

In this cas than
that indica re
clinical sig

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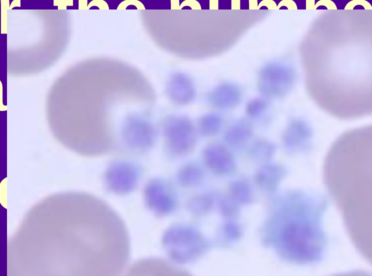
menu

# Effects of giant platelets and platelet clumps?

When <u>giant platelets or platelet clumps</u> are present in peripheral blood, they too will be included in the RBC count. For example…

However, the number present is usually too low to cause a clinica R nt.

It is imp p umps are seen:

- the automated platelet count (PLT) is inaccurate (the true PLT would be higher).
- estimated platelet counts from blood smears may also be inaccurate (the true PLT estimate would be higher).

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menu

# Of what clinical importance are RBC counts?

RBC counts (as well as hemoglobin concentration and HCT) may be abnormal in disease states. RBC counts are characteristically:

d
e
c
r
e
a
s
e
d

- Anemia
- Blood loss
- Some leukemias

&

i
n
c
r
e
a
s
e
d

- Polycythemia vera

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# End of Total RBC Count

**This concludes the Total RBC Count Section. Select one of the following:**

**Go to Hemoglobin, the section, to with the exercise as designed.**

**OR**

**Return to the Hemogram Menu and make an alternate selection.**

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menu

# Hemoglobin

# What is hemoglobin (HGB)?

**Hemoglobin**, a conjugated protein, is the main component of the red blood cell.

It's major function is to **transport**:

$O_2$ from lungs to tissues

and

$CO_2$ from tissues to lungs

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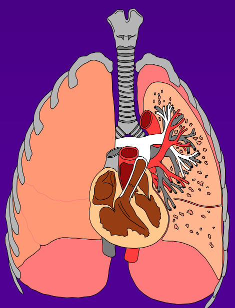
menu

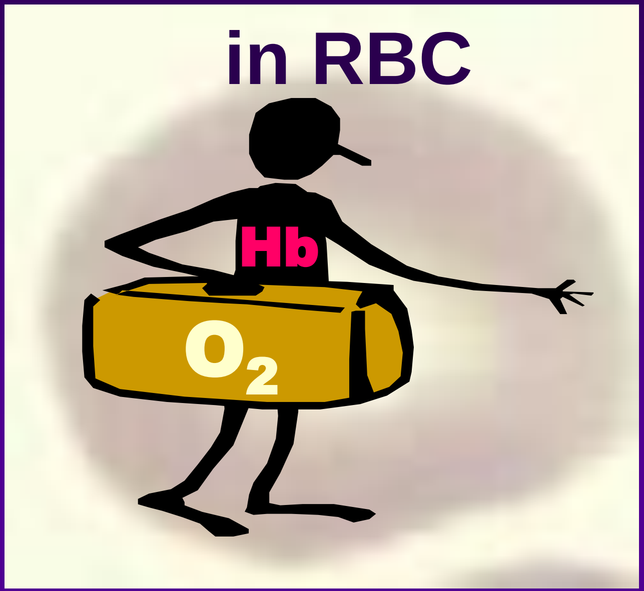
# How does HGB transport $O_2$ and $CO_2$?

from lungs

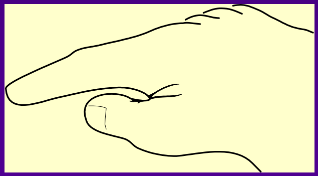
$O_2$ transported



(high tension)




to tissues (eg, hand)

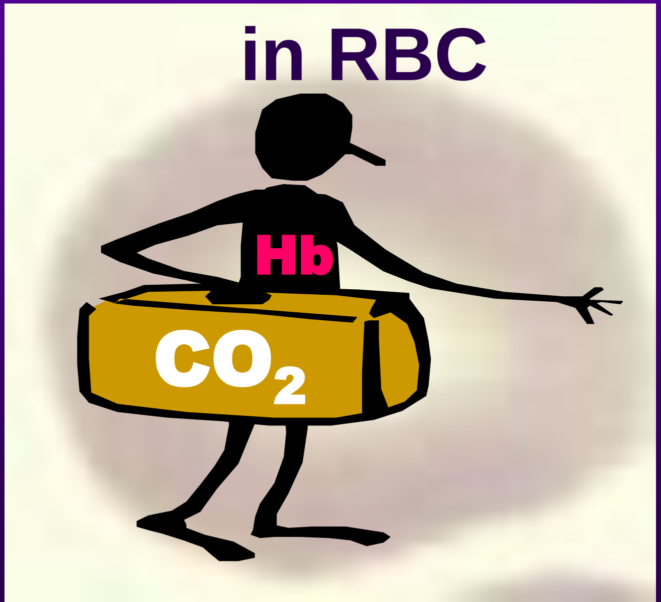


(low tension)

and

in exchange from tissues

$CO_2$ transported




back to lungs

csw lsuhsc 2001

menu

# Of what clinical importance are hemoglobin values?

Abnormal hemoglobin concentrations may be seen in disease states. Hemoglobin concentrations, as well as RBC count and HCT, are characteristically:

decreased

- Anemia
- Blood loss
- Some leukemias

&

increased

- Polycythemia vera

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menu

# End of Hemoglobin

This concludes the Hemoglobin Section. Select one of the following:

Go to Hematocrit, the next section, to continue with the exercise as designed.

OR

Return to the Hemogram Menu and make an alternate selection.

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menu

# *Hematocrit*

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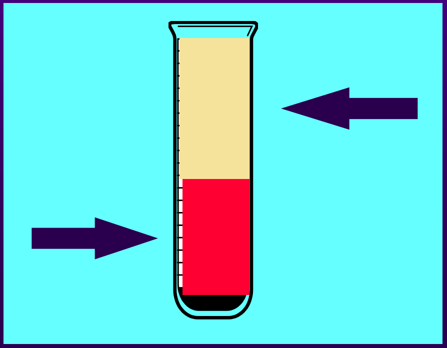
menu

## What is the hematocrit (HCT)?

The **hematocrit** is a reflection of the concen-tration of red cells, not of the total red cell mass.

Therefore, by definition, the hematocrit is the relative volume of packed erythrocytes expressed as a percentage of the volume of whole blood sample, e.g.:

40% packed cells
or 40% HCT



&

60% plasma

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menu

# Of what clinical importance are hematocrit (HCT) values?

Abnormal hematocrits may be seen in disease states. Hematocrit values, as well as RBC count and HGB concentrations, are characteristically:

**decreased**

- Anemia
- Blood loss
- Some leukemias

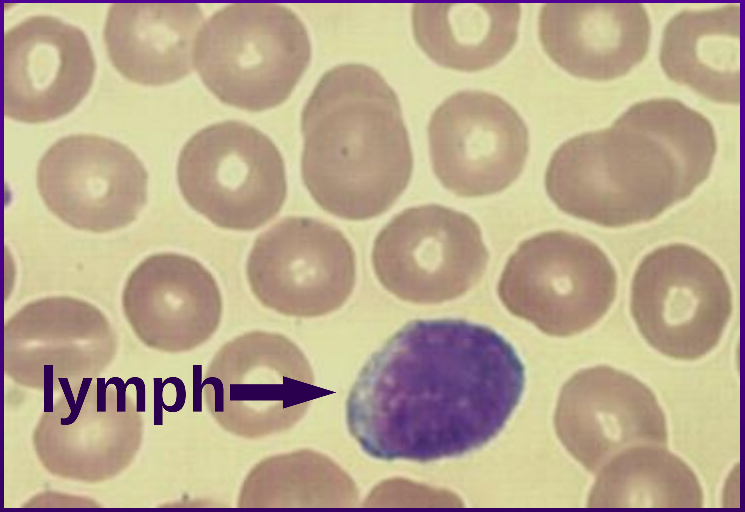
&

**increased**

- Polycythemia vera

# How does the HCT correlate with the RBC count when RBC are normocytic?

**When erythrocytes are normocytic, there is good correlation of the HCT and the total RBC count (i.e., when one is low, the other is low; when one is high, the other is high).**




**RBC of normal size and shape are called normocytic. They are about 6-8μm in diameter (slightly smaller than the nucleus of a normal, small lymphocyte which is about 8-10 μm in diameter).**

**Normal red cells are round and biconcave with a slight central pallor.**

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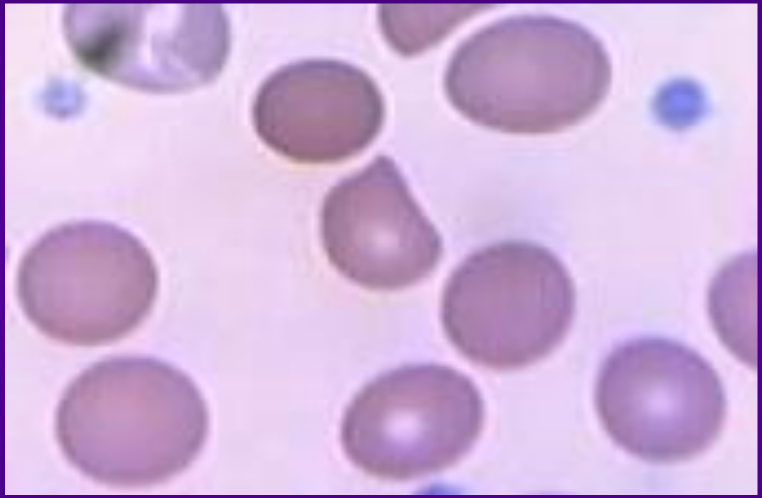
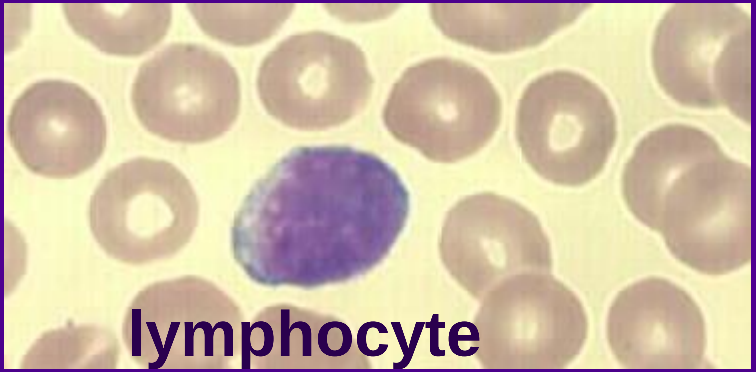
menu

# How does the HCT correlate with the RBC count when the RBCs are macrocytic?

In macrocytosis, because the RBC are larger than normal,



(normocytic cells)




the total RBC count may be lower than expected based upon HCT values.

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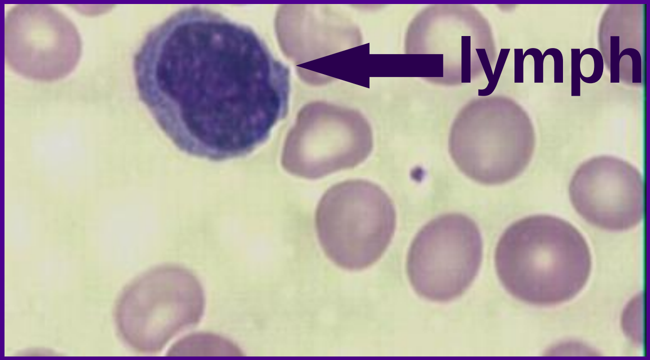
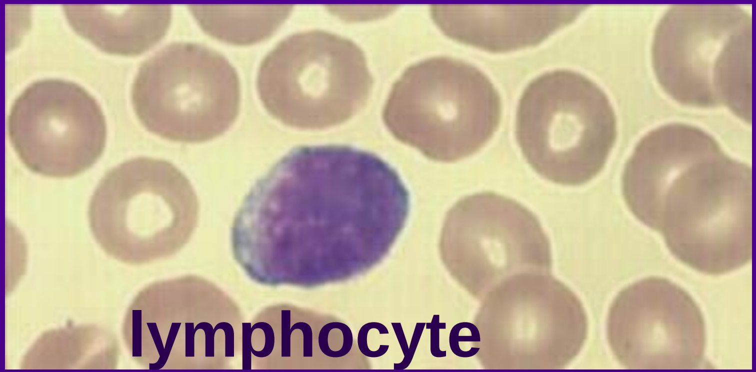
## How does the HCT correlate with the RBC count when the RBC are microcytic?

In microcytosis, because the cells are smaller than normal,

(normocytic cells)




the total RBC count may be higher than expected based upon HCT values.

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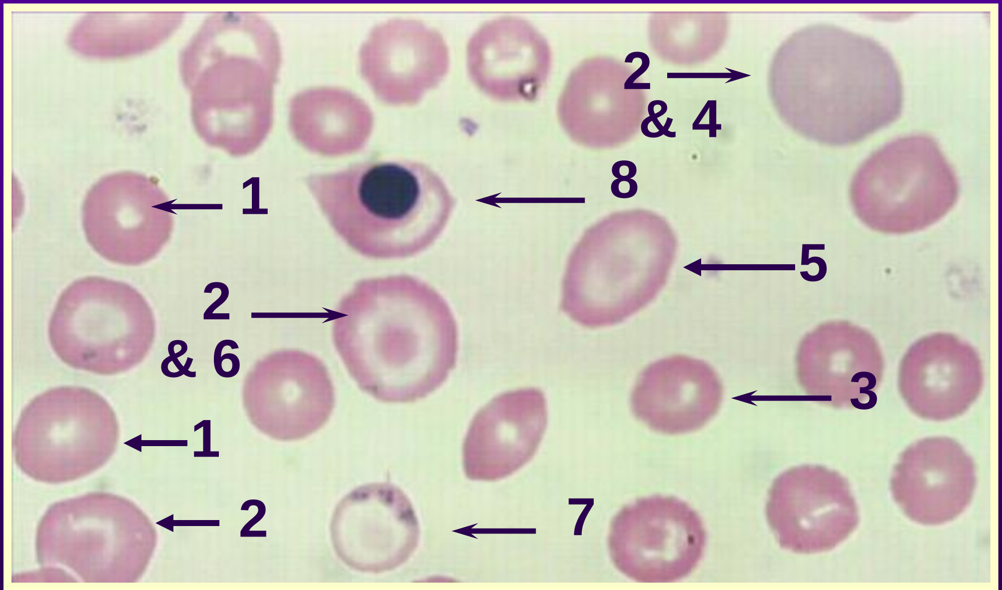
menu

# How does the HCT correlate with the RBC count in a mixed RBC population?

The instrument electronically measures and determines a mean volume of the cell population, e.g.,

- 1 normal mature RBC
- 2 macrocytes
- 3 microcytes
- 4 polychromatophilic erythrocyte
- 5 ovalocytes
- 6 target cells
- 7 RBC with inclusions
- 8 NRBC




Because of the variation in cell size and volume, correlations of RBC, MCV, and HCT becomes less predictable.

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# What are some examples of true HCT/RBC inconsistencies?

**In hydremia of pregnancy:**

**the HCT is low although there is no reduction in the total number of circulating red cells.**

**and**

**In shock accompanied by hemoconcentration:**

**the HCT may be normal or even high though blood loss may have caused a considerable decrease in the total red cell mass.**

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# What is the correlation between HCT and hemoglobin (HGB)?

HCT (expressed in per cent) is usually roughly 3 times the HGB (expressed in g/dL).

**For example:**

An adult with hematocrit of 45% would normally have a hemoglobin of about 15 g/dL.

**Further discussion:**

The relationships between the HCT and total RBC count and the HCT and HGB concentration are discussed further in the section on RBC indices.

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menu

# End of Hematocrit

**This concludes the Hematocrit Section. Select one of the following:**

**Go to Erythrocyte (RBC) Indices, the next section to continue with the exercise as designed.**

**OR**

**Return to the Hemogram Menu and make an alternate selection.**

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menu

# Erythrocyte (RBC) Indices

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# What are the erythrocyte (red blood cell) indices?

The indices are measurements of the:

- average volume or size of red cells (MCV)
- hemoglobin content or weight in the average red blood cell (MCH)
- hemoglobin concentration in a given volume of red blood cells (MCHC).

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menu

# Of what clinical value are the erythrocyte (red blood cell) indices?

The indices are valuable tools in the study of anemias because they provide an objective quantitative standard for assessing the

- size of the red cells (MCV)
- relationship between individual blood cells and the hemoglobin concentration (MCH)
- red blood cell population as a whole and the hemoglobin concentration (MCHC).

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menu

## What method is used to determine the erythrocyte (RBC) indices today?

When first introduced, all of the indices (MCV, MCH, and MCHC) were calculated values based on accurate direct measurements of the RBC, HGB, and HCT (packed cell volume).

Today , with the use of modern technology, it is the MCV that is now measured directly and the HCT that is calculated.

Let us look at the measurements included in the indices.

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# What are the measurements in the erythrocyte indices?

**MCV**

**(mean corpuscular volume $\mu^3$)**

**MCH**

**(mean corpuscular hemoglobin $\mu\mu g$)**

**MCHC**

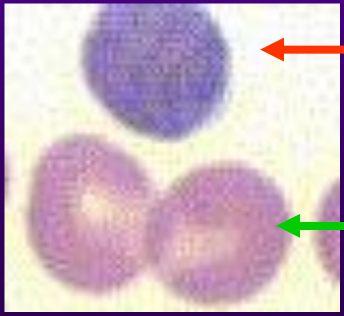
**(mean corpuscular hemoglobin conc. %)**

# What is the MCV?

**MCV is the <u>average volume</u> <u>(or size)</u> of red cells expressed in $\mu^3$ or femtoliters (fL).**

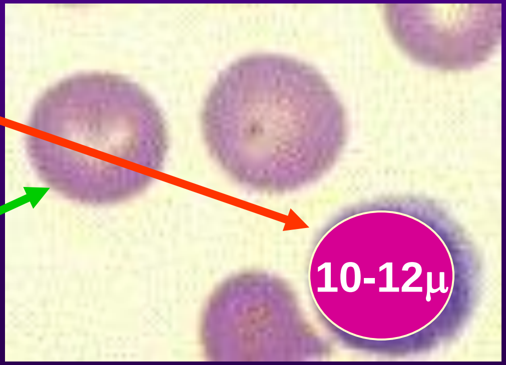
**Individuals with normal peripheral blood will have a normal MCV (i.e., 80-100 $\mu^3$).**

**The normal small mature lymphocyte, because it is relatively consistent in size with a nucleus that is about 10-12μ in diameter, is a useful tool in a visual assess-ment of red cell size on stained blood smears.)**



lymphocyte
(nucleus 10-12μ)

normal RBC
(6-8μ)



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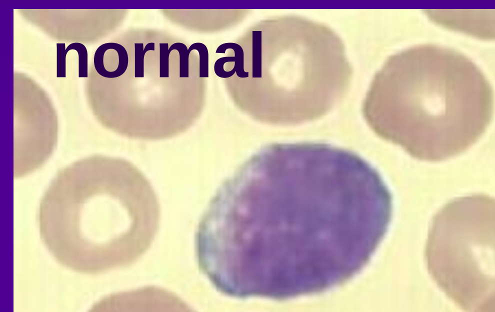
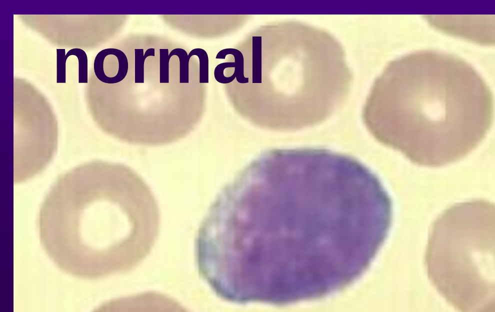
# What affect do abnormally large or small red cells have on the MCV?

**Individuals with red cells that are predominantly larger than normal (>8m diameter) will have an MCV >100 μ$^3$.**


**Individuals with red cells that are predominantly smaller than normal (<6m diameter) will have an MCV < 80 μ$^3$.**

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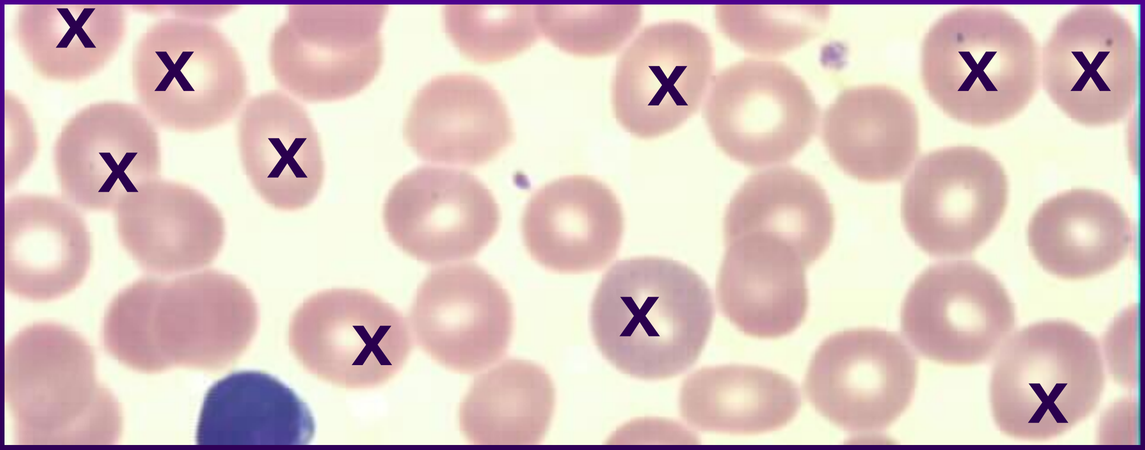
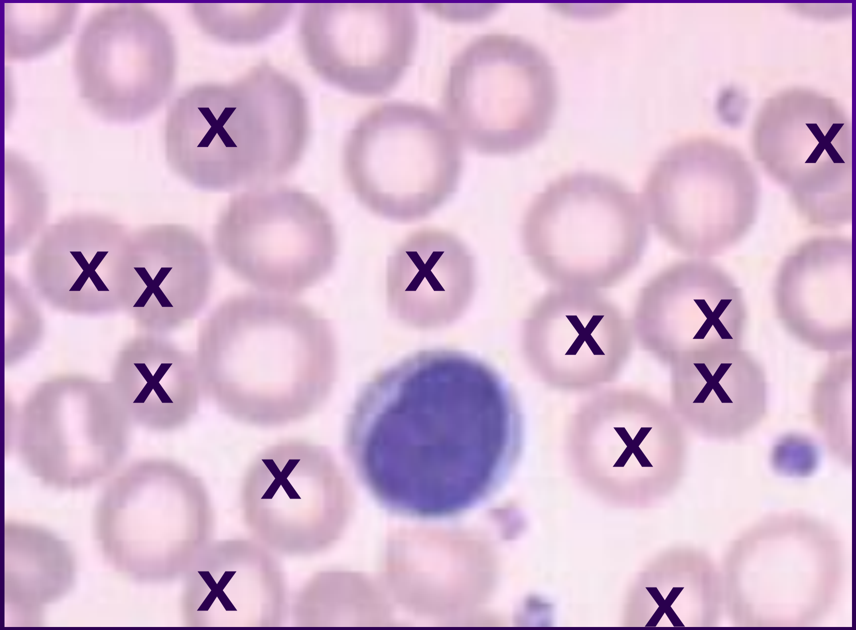
# What if there are various sizes of red cells?

E.g., macrocytic and normocytic RBC: it is important to remember that the MCV is the average volume (or size) of the cells. For example, if an MCV is high, it does not mean that all of the red cells are larger. Some of the cells may be normal or even smaller than normal. It is an indication, however, that large cells are present in sufficient numbers to cause an increased MCV, e.g..



# And conversely,

If the MCV is low, it does not necessarily mean that all of the cells are smaller than normal. It is an indication, however, that the number of small cells is sufficient to cause a decreased MCV, e.g.:



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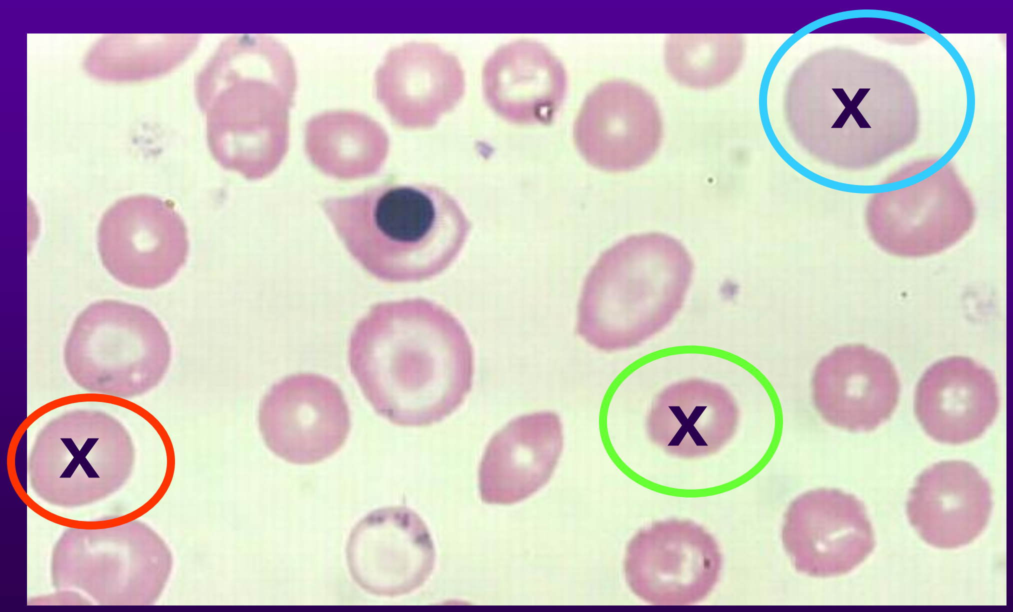
# Does a normal MCV always indicate a normal RBC population?

Again, it is important to remember that the MCV is the average volume (or size) of the cells. A patient with a red cell population of varying sizes that include normocytic and/or microcytic and/or macrocytic cells may have a normal MCV. e.g.:

normocytic

microcytic

macrocytic



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# Then what is the best way to evaluate a mixed population of RBC?

**Microscopic examination of the peripheral blood smear provides a better evaluation of MCV when a mixed population of red cells is involved or when interference is suspected.**

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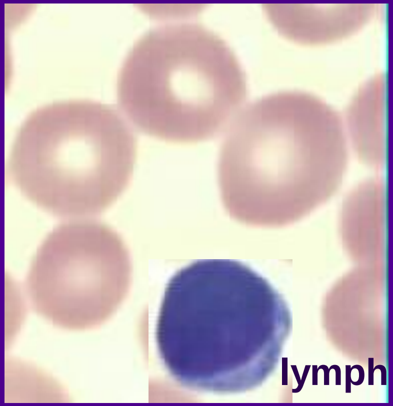
menu

# Of what clinical importance are MCV values?

**MCV values may be abnormal in disease states. E.g., MCV is characteristically elevated in:**

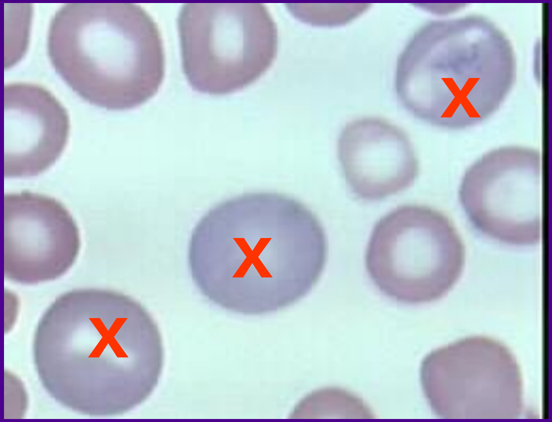



**macrocytic anemias**

**and**

**may be as high as 150 $\mu^3$ (or fL) if megaloblastic**


**and**




**polychromasia or reticulocytosis (e.g., hemolytic anemias, acute blood loss)**

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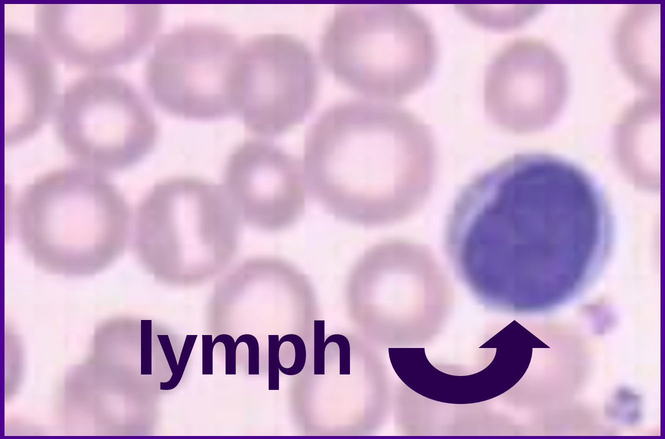
menu

# Clinical importance of decreased MCV values (continued)…

**…and characteristically decreased in:**




**Microcytic hypochromic anemia and may be as low as 50 $\mu^3$ (or fL).**

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# What is the second measurement included in the RBC indices?

In addition to the:

MCV (mean corpuscular volume $\mu^{3}$)

There is the MCH.

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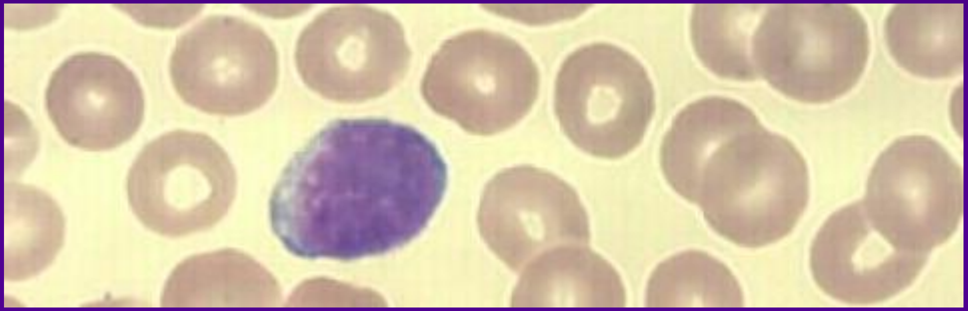
# What is the MCH?

**MCH is the content (or weight) of hemoglobin of the average red cell (i.e., individual cells) expressed in micromicrograms (μμg) or picograms (pg).**



**The MCH is a calculated measurement based on the values obtained for the HGB concentration and the RBC count.**

**An individual whose red cells are normal (i.e., size, shape with slight central pallor) will have a normal MCH, even if the HGB and RBC values are decreased.**

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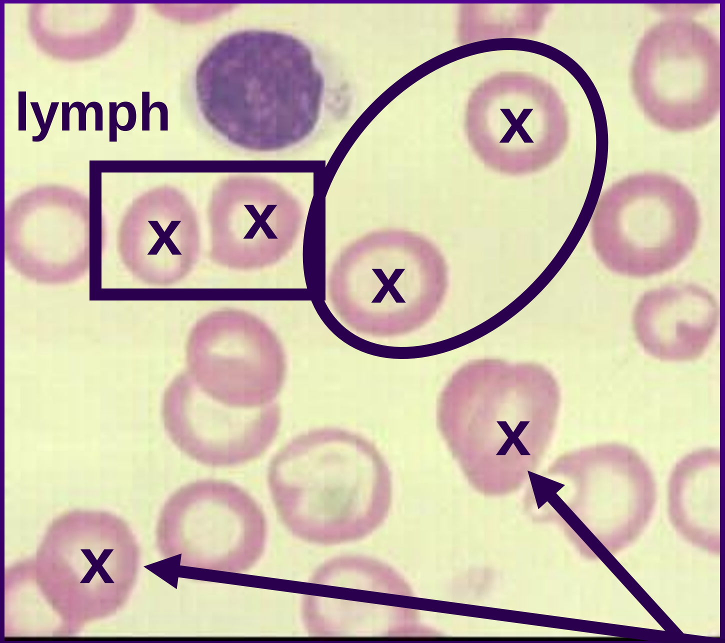
# What about individuals with a decreased MCH?

A **low MCH** indicates a less than normal hemoglobin content in the average individual red cell (hypochromic erythrocytes). In some cases, the cells may also be microcytic (< 6 μm in diameter).




Again, this is an average.

lthough many RBC are microcytic hypochromic

d/or normocytic hypochromic,

some may be normochromic

# Of what clinical importance are MCH values?

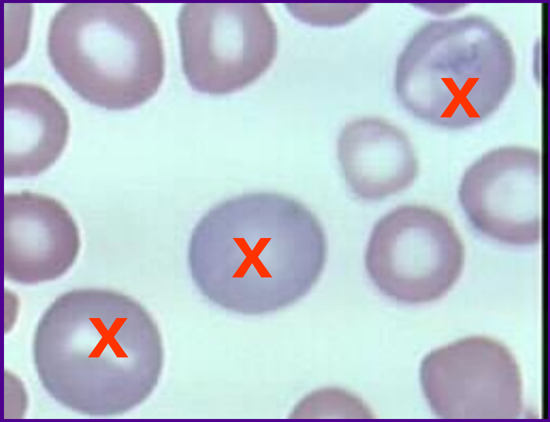
MCH values may be abnormal in disease states. E.g., MCH is characteristically elevated in:


macrocytic anemias

and

may be as high as 50 μμg (or pg) if megaloblastic


and




polychromasia or reticulocytosis (e.g., hemolytic anemias, acute blood loss)

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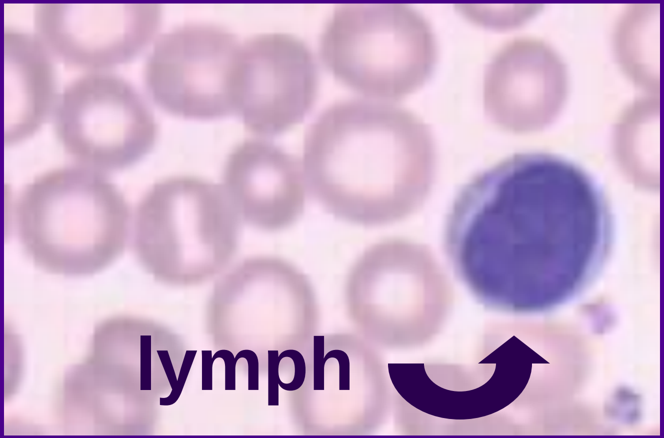
# Clinical importance of MCH values, (continued)

## Characteristically decreased in:




**Microcytic hypochromic anemia and may be as low as 15 μμg (or pg).**

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# What is the third measurement included in the RBC indices?

In addition to the:

MCV (mean corpuscular volume $\mu^3$)

and

MCH(mean corpuscular hemoglobin $\mu\mu g$)

There is the MCHC.

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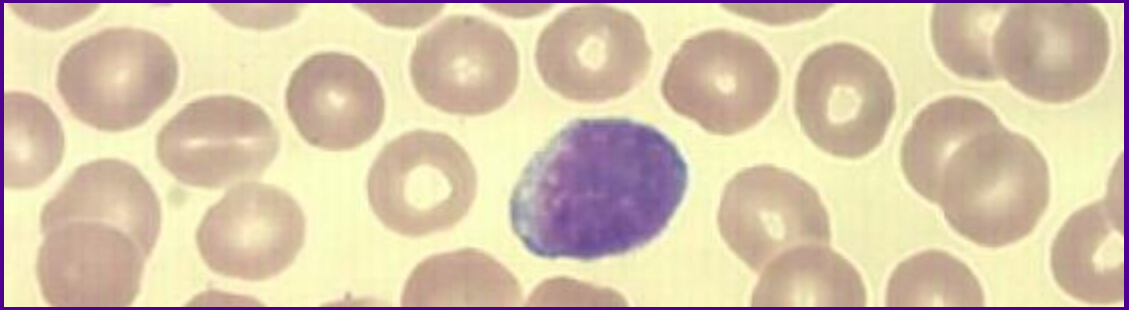
# What is the MCHC?

**MCHC is the average hemoglobin concentration in a given volume of packed RBC expressed in g/dL (or %).**



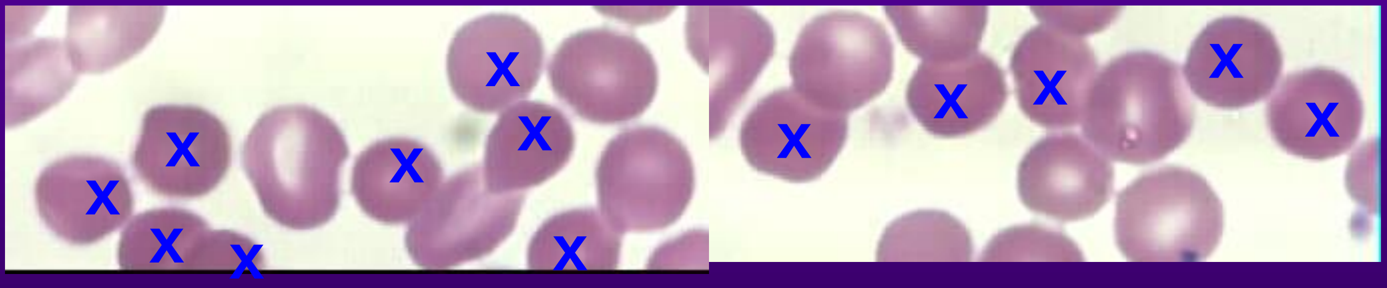
**MCHC is based on the relationship between the HGB concentration and the HCT and is calculated using the values obtained for those two measurements.**

**An individual whose red cells are normal (i.e., size, shape with slight central pallor) will have a normal MCHC even if the HGB and HCT are decreased.**

# Of what clinical importance is the MCHC value?

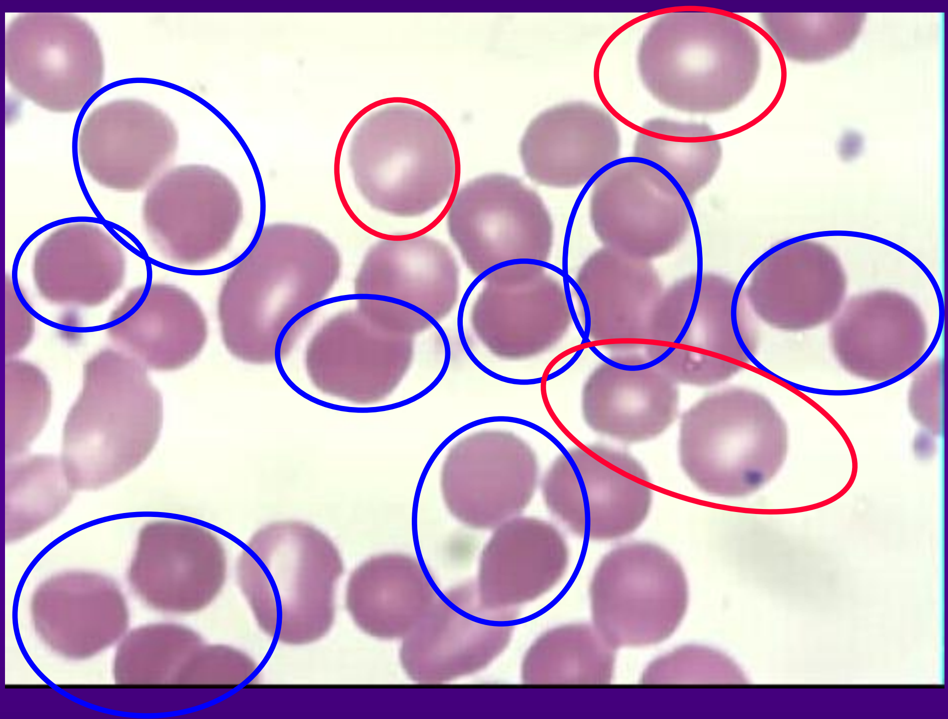
MCHC values may be abnormal in disease states.

A true elevated MCHC is seen only in spherocytosis.



menu

# How do spherocytes differ from normal RBCs ?

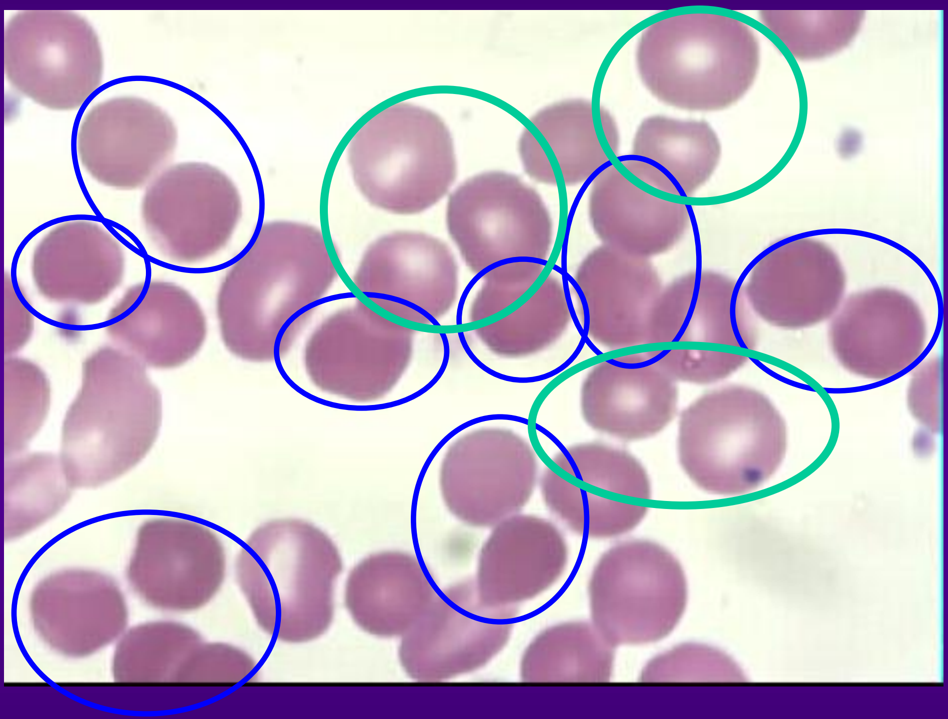


**Spherocytes, (circled in blue) are round and have no central pallor.**

**Normocytic red cells (circled in red) have a slight central pallor (about 1/3 of the cell diameter) due to the biconcave shape**

# Why is a true elevated MCHC seen only in spherocytosis?





It's the only situation in which the cells are spherical and,

therefore, have a greater capacity for hemoglobin than biconcave cells.

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## What other disorders are characterized by an ↑ MCHC?

**In the absence of spherocytosis, an elevated MCHC may be an indication**

**of**

**A falsely elevated MCV and decrease in HCT (e.g., caused by cold agglutinins)**

**or**

**Falsely elevated HGB (e.g., lipemia or some other interfering factor).**

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## What disorders are characterized by a ↓ MCHC?

**Normal or decreased:**

macrocytic anemias

**Decreased:**

hypochromic anemia (usually no lower than 22 %)

**Normal MCHC but reduced HGB & HCT:**

normochromic anemias

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# How are the RBC indices calculated?

When determined by automated electronic instruments, the MCV is a direct measurement.

A calculated indirect MCV measurment can be made using microhematocrit values.

$$\text{Calculated MCV} = \frac{\text{Micro HCT (\%)} \times 10}{\text{RBC (millions/}\mu\text{L)}}$$

MCH and MCHC are always calculated.

$$\text{MCH} = \frac{\text{HGB (g/dL)} \times 10}{\text{RBC (millions/}\mu\text{L)}}$$

$$\text{MCHC} = \frac{\text{HGB (g/dL)} \times 100}{\text{HCT (\%)}}$$

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# End of RBC Indices

This concludes the Erythrocyte (RBC) Indices Section. Select one of the following:

Go to Red Cell Distribution Width (RDW), the next section, to continue with the exercise as designed.

OR

Return to the Hemogram Menu and make an alternate selection.

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# Red Cell Distribution Width

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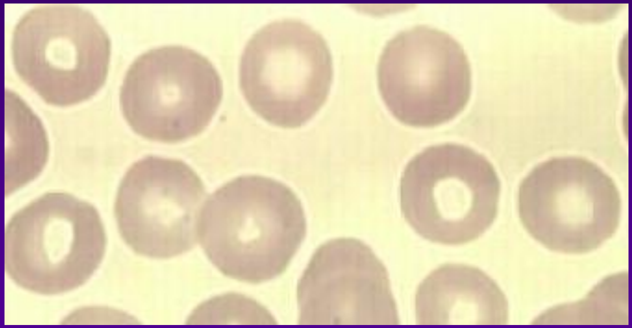
# What is the Red Blood Cell Distribution Width (RDW) ?

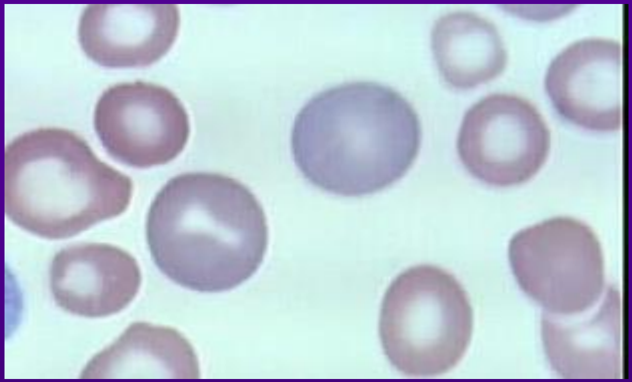
## Normally

All red cells are approximately the same size and measure about 6-8μ in diameter.



## Anisocytosis

A “generic” term used to indicate a subjective visual assessment of abnormal variation in size of red cells



## The RDW

An objective electronic measurement of the variation in the size of the cells in the RBC population

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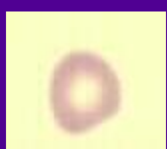
# How is the RDW determined?

**Based on data obtained by electronic measurement of the sizes of the red cells, the RDW is calculated by enumerating the number of erythrocytes that are:**

**smaller**

**than the reference (normal) cell volume (size)**

**or larger**



**⬇ MCV**

**normal MCV**

**⬆ MCV**

**Thus, based upon objective measurements, the RDW provides an estimate of anisocytosis (i.e., variation in size of the red cells).**

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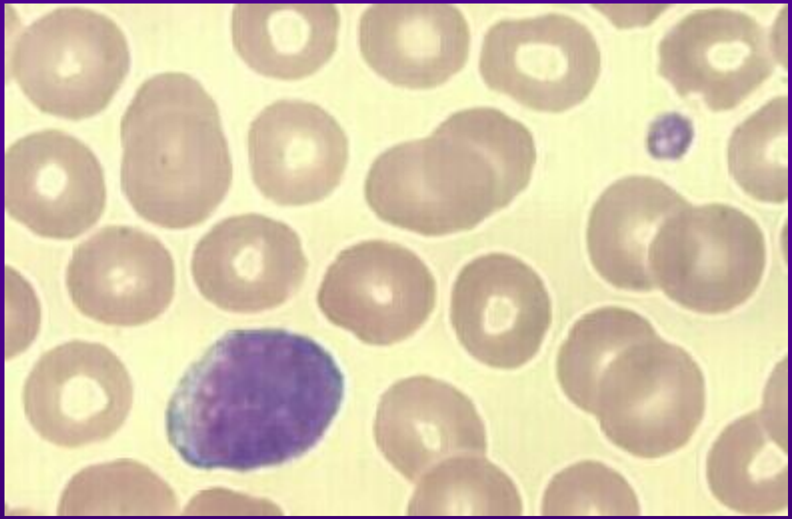
# When are normal RDW values seen?

Normal RDW values of 11.6-14.6 (which may vary slightly among laboratories) are seen when the RBC are all about the same size.



(i.e., essentially homogeneous RBC population)

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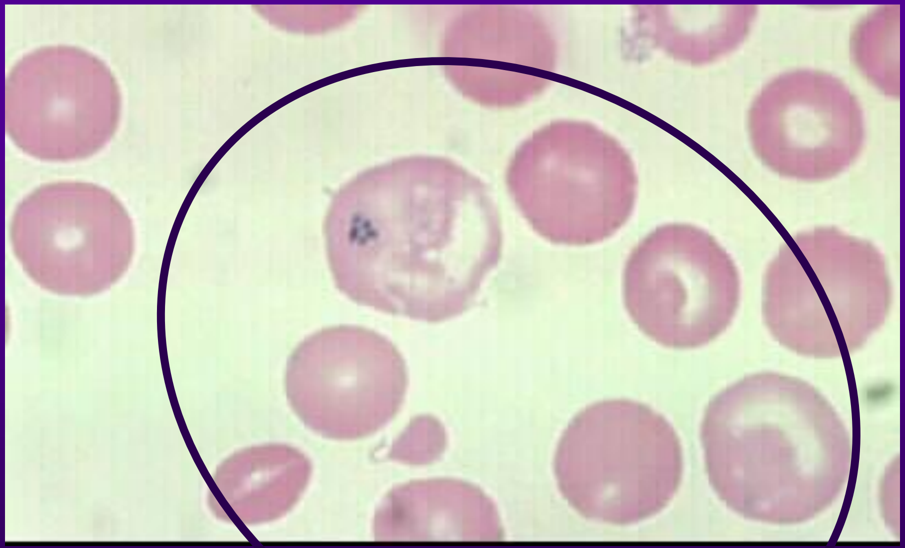
# When are increased RDW values seen?

In disease, an **increased RDW** may be seen proportionate to the degree of variation in size of the red blood cell population (i.e., the greater the anisocytosis, the greater the RDW).

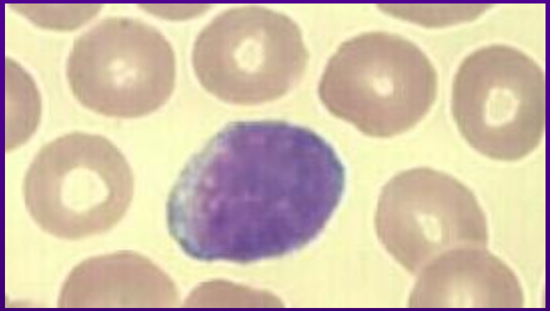
e.g.



# When are decreased RDW values seen?

**The RDW is never decreased (i.e., less than the lower reference value). Think about what is being measured.**

**A normal RDW reflects an RBC population in which the cells are essentially the same size.**



**An increased RDW reflects a population with variation in size.**

**Those are the only two possibilities so the RDW can never be decreased.**

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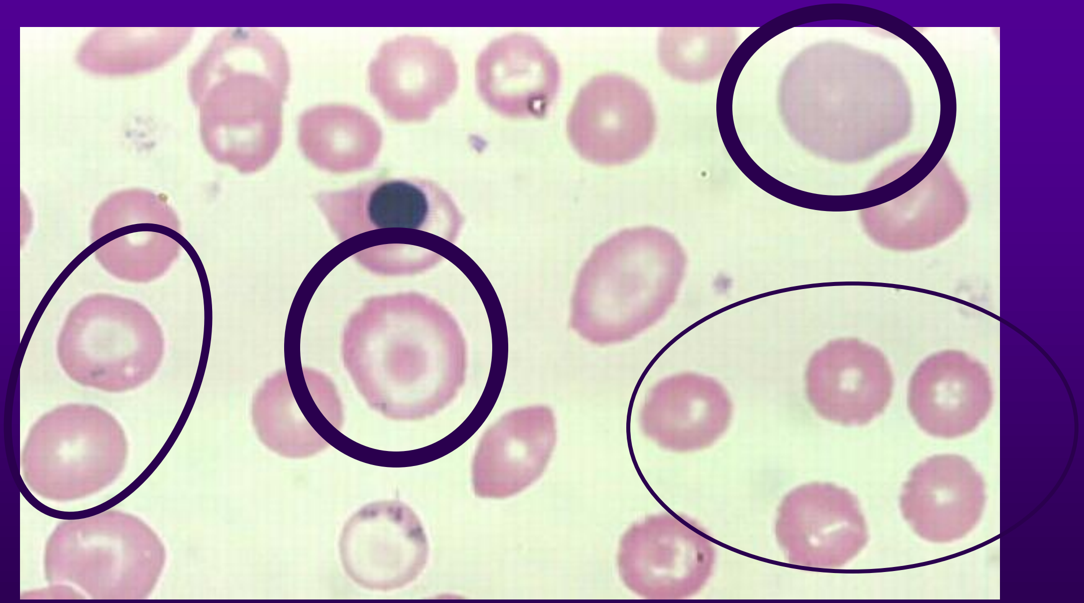
# What causes the change in RDW?

**Variability in the size of the cells in the RBC population causes the increased RDW. The increase may reflect an RBC population containing any combination of abnormal and normal (or less affected) red cells, for example…**



**normocytic**

**and**

**microcytic**

**and/or**

**macrocytic**

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# What is the clinical importance of the RDW?

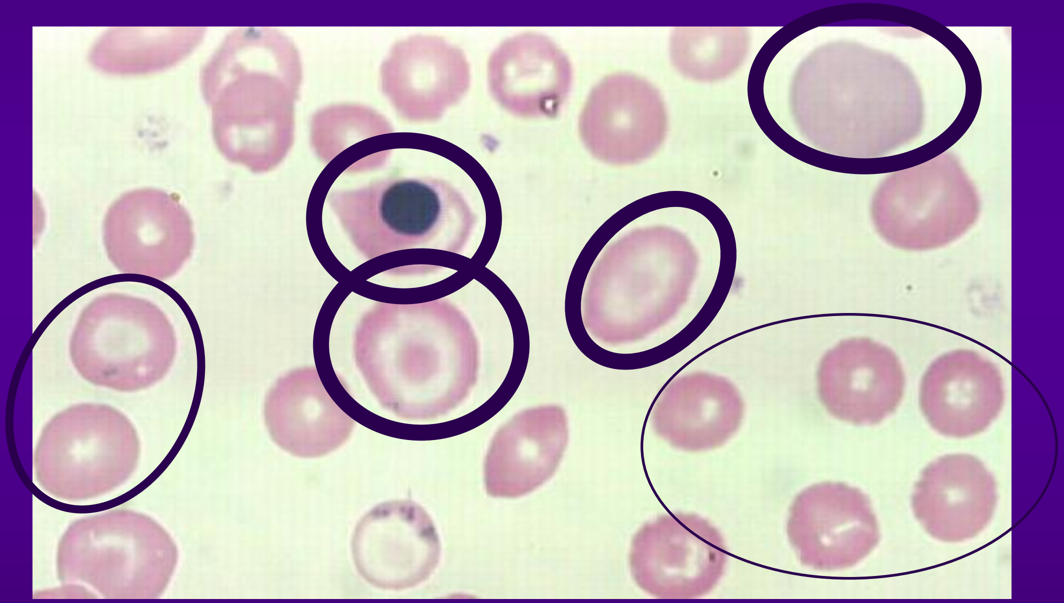
**RDW** is the most sensitive measurement involving red cells.

**RDW** is the first to become abnormal (sometimes before anemia appears).

**RDW** is the first to become abnormal in iron deficiency due to chronic blood loss.

# Do the RDW and MCV measurements provide the same information?

Remember, the **MCV** is the <u>average</u> cell volume of <u>all</u> circulating blood cells (for example):



normocytic,

&

macrocytic,

&

microcytic

In this case, the MCV could be within reference range after averaging the normal size, large, and small cells included in the measurement.

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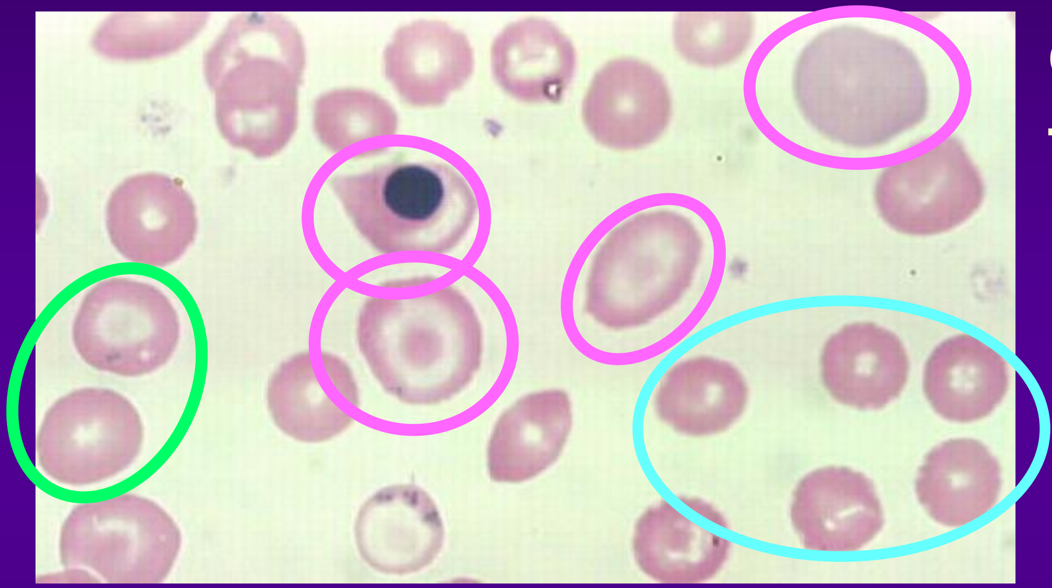
# How does the MCV differ from the RDW?

Whereas the MCV is the average cell size (volume)



of a population that may include

normocytes,

macrocytes, and

microcytes,

the RDW reflects the degree of variation in the sizes of those blood cells. In this case, while the MCV (average size) could possibly be within normal limits, the RDW would be increased.

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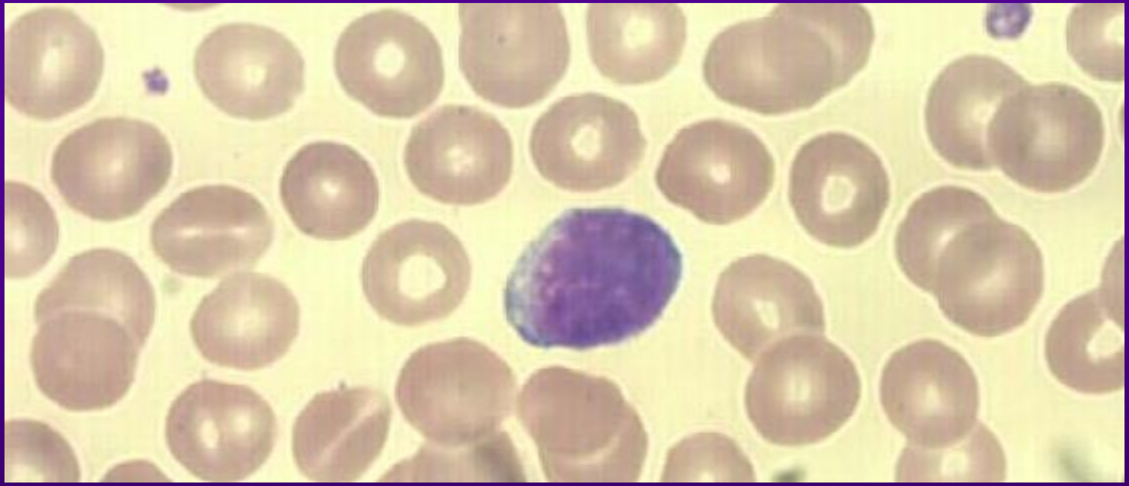
# Is there any relationship at all between the RDW and MCV?

Both the MCV and RDW are expected to be normal when the RBC population is relatively homogeneous in size (i.e., essentially one size).



What about abnormal RBC populations?

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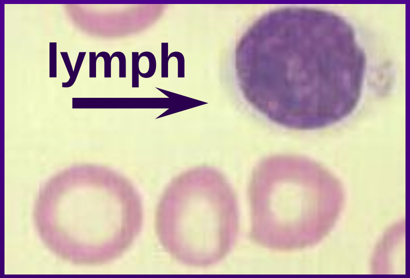
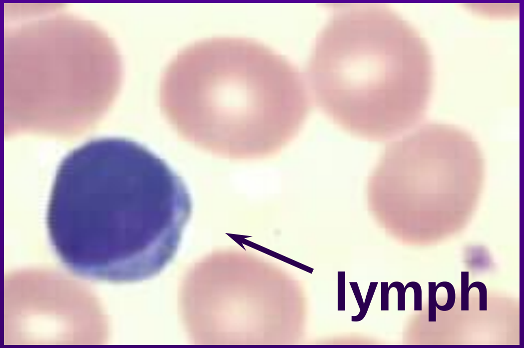
# Can a low or high MCV be expected if the RDW is normal?

Certain conditions are characterized by red cells that, although essentially the same size, are smaller (or larger) than normal. In those conditions, a normal RDW will be found even though the MCV is low (or high).




homogeneously micro-cytic & low MCV

or




homogeneously macro-cytic & high MCV

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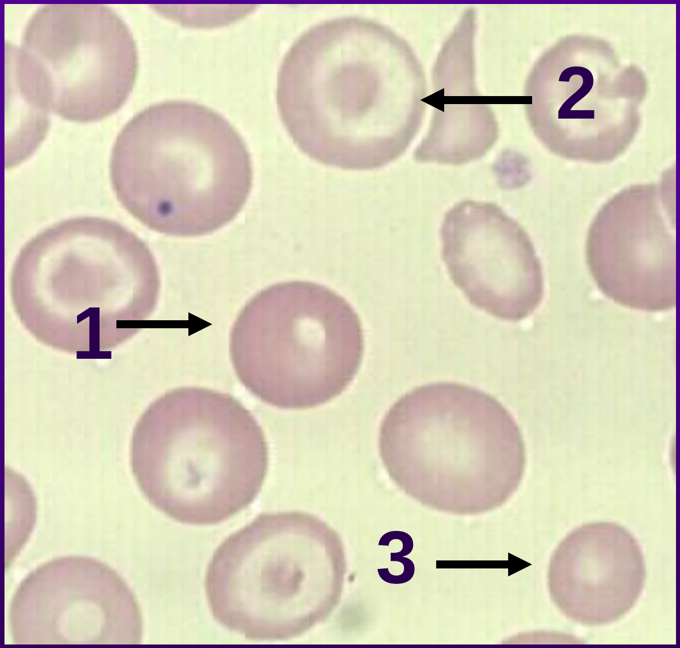
# Can a normal MCV be expected if the RDW is abnormal?

Even in cases where the population of blood cells includes cells of varying size (i.e., abnormal RDW), the MCV may be normal because it reflects the average cell volume of all of the cells , e.g.:

[1] normocytic,

[2] macrocytic, and/or

[3] microcytic.



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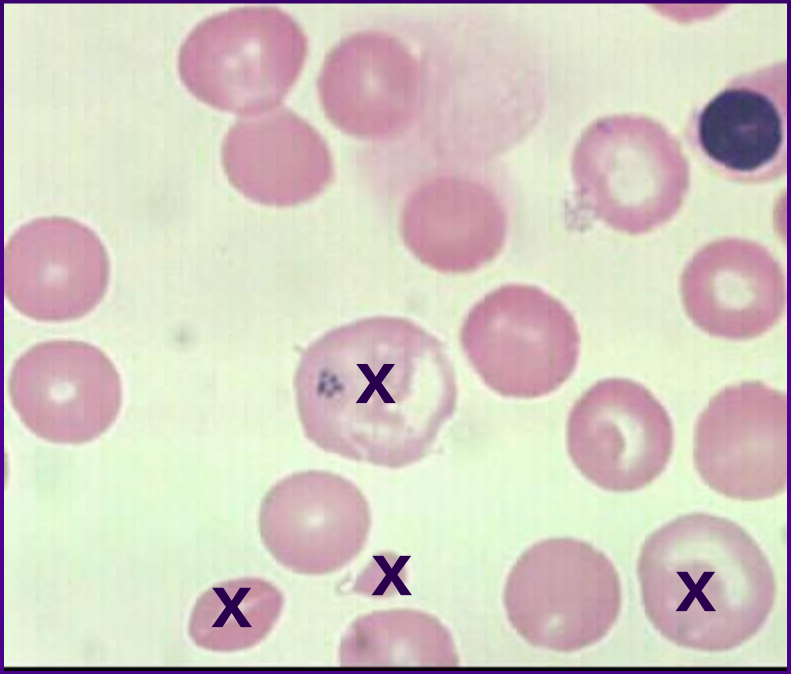
In cases where the MCV is normal and the RDW is abnormal,




the RDW will be increased proportionately to the number of cells smaller or larger than normal and the degree of variability in cell size.

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# Examples in which both the RDW and MCV may be normal…

| RDW | MCV | Conditions |
| --- | --- | --- |
| Normal | Normal (homogenous normocytic RBC population) | good health |
| Normal | Normal (homogenous normocytic RBC population) | chronic disease (90% of cases are normocytic)<br>uremia<br>HbAS<br>HbAC |

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# Examples in which the MCV is abnormal but the RDW may be normal…

| RDW | MCV | Conditions |
|---|---|---|
| Normal | Low (homogenous microcytic red cells) | thalassemia minor<br>iron deficiency<br>chronic disease (10% of cases are microcytic) |
| Normal | High (homogenous macrocytic red cells) | aplastic anemia<br>myelodysplastic syndrome<br>anemia due to alcoholism |

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# Examples of conditions in which the RDW is increased and MCV is likely to be normal…

| RDW | MCV | Conditions |
| --- | --- | --- |
| High | Normal<br>(average size of cells in a heterogenous RBC population) | early factor deficiency<br>HbSS disease<br>HbSC disease |

# Examples of conditions in which the RDW is increased but the MCV may be decreased…

| RDW | MCV | Conditions |
|---|---|---|
| High | Low (average size of cells in severe anemias charac-terized by microcytic RBC and/or abnormalities associated with hemolytic alterations such as RBC fragments) | HbS-thalassemia<br>thalassemia major<br>HbH disease<br>hereditary spherocytosis<br>TTP<br>DIC |

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# Examples of conditions in which both the RDW and the MCV may be increased…

| RDW | MCV | Conditions |
| --- | --- | --- |
| High | High<br>(average size of cells in severe anemias char-acterized by macrocytic alterations in the RBC population) | vitamin B12 deficiency<br>folate deficiency<br>reticulocytosis (e.g., acute blood loss, autoimmune hemolytic anemia<br>newborn (due to presence of immature RBC)<br>cold agglutinins (due to false values) |

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## Examples of conditions with a decreased RDW and their expected MCV.

| RDW | MCV | Condition |
|---|---|---|

**If you were expecting to see a list of conditions, you have not been paying attention. The RDW is <u>never</u> decreased.**

**You may review the section on RDW or .**

**review RDW or continue**

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# End of Red Cell Distribution Width

This concludes the Red Cell Distribution Width (RDW) Section. Select one of the following:

Go to Platelet Count, the next section, to continue with the exercise as designed.

OR

Return to the Hemogram Menu to review a section on one of the parameters of the Hemogram.

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# Platelet Count

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# What is a platelet count (PLT)?

The total platelet count is the **number of platelets** per given volume of peripheral blood (e.g., 200,000/μL).

Platelets are **difficult to count**.

- They are small & must be differentiated from debris.
- They have a tendency to adhere to glass, to any foreign body, and to each other which may cause a false low count to be obtained.

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# Are there special specimen requirements for platelet counts?

**Platelet counts must be performed within:**

- **3 hours after collection in an EDTA anticoagulated tube of blood.**
- **1 hour after collection in a unipette containing diluent (finger stick)**

**In vitro changes:**

**The MPV (mean platelet volume) increases after 3 hours (at least in part as a result of the change in cell shape).**

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# How can platelet counts be verified?

Questionable counts are verified by microscopic examination of a stained blood smear. Examine for:

- platelet clumps
- platelet distribution (evenly throughout smear)
- platelet estimate (1 platelet per oil immersion field on a smear is equivalent to approximately 15,000 to 20,000 platelets)

Extremely low electronic counts are verified by phase microscopy (i.e., manual hemacytometer count).

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## Of what clinical importance are platelet counts?

To be hemostatically effective, platelets must be present in sufficient numbers and must be functionally normal. **Platelet disorders** may be classified as:

**Qualitative** (i.e., defect in the functional ability of platelets)

**or**

**Quantitative** (i.e., increase or decrease in the number of platelets), as determined by the platelet count.

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# What disorders are associated with a quantitative increase in platelets?

**Thrombocytosis,** an abnormal increase in PLT, may be due to:

**Reactive thrombocytosis:**

A physiologic response that may be seen as a secondary phenomenon (eg, in trauma, hemorrhage, iron deficiency)

**Temporary rise in platelets:**

May be seen following splenectomy (splenic pool is eliminated)

**Autonomous (primary thrombocythemia):**

A primary bone marrow disorder commonly seen in myeloproliferative disorders.  Platelets may also have functional abnormalities.

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# What disorders are associated with a quantitative decrease in platelets?

**Thrombocytopenia, an abnormal decrease in platelets may be attributed to:**

**Decreased production:**

**Due to a quantitative or hypoproliferative defect in mega-karyocytes (e.g., marrow damage, replacement of normal marrow by metastatic tumor, intrinsic marrow disease [leukemia]),**

**Ineffective thrombopoiesis:**

**A normal number of marrow megakaryocytes, but platelet production is decreased (e.g., megaloblastic anemias)**

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# Quantitative platelet decreases, (continued)

**With increased destruction of platelets, characterized by megakaryocytes in the bone marrow and low platelet counts in peripheral blood, PLT destruction may be due to:**

**Non-immune (consumptive) causes, e.g.:**

- **disseminated intravascular coagulation (DIC)**
- **thrombotic thrombocytopenic purpura (TTP)**

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menu

# Quantitative platelet decreases (continued)

May also be due to immune causes, e.g.:

- drug-induced immune thrombocytopenia
- acute and chronic idiopathic thrombocytopenic purpura (ITP)

Decreases may also be due to increased spleen pooling.

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# End of Platelet Count

**This concludes the Platelet Count Section. Select one of the following:**

**Go to <u>Mean Platelet Volume (MPV)</u>, the next section, to continue with the exercise as designed.**

**OR**

**Return to the <u>Hemogram Menu</u> and make an alternate selection.**

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# Mean Platelet Volume

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# What is the Mean Platelet Volume (MPV)?

**The mean platelet volume (MPV) is the average volume or size of the platelets in the population.**

**Once the platelet count and size distribution is determined, the mean platelet volume can be calculated from the arithmetic mean of the extrapolated histogram.**

**MPV reference values are about 6.5 to 12 fL.**

**Normally, the platelet size varies inversely with the platelet count.**

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## Is platelet size affected if there is an abnormal PLT count but normal marrow function?

Platelet size also varies inversely with abnormal platelet counts when there is normal marrow function, e.g.:

| Disorder | PLT count | MPV |
| --- | --- | --- |
| idiopathic thrombocytopenia | ↓ | ↑ |
| reactive thrombocytosis | ↑ | ↓ |

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## Is platelet size affected if both PLT count and marrow function are abnormal?

If there is abnormal marrow function (e.g., folate deficiency or aplastic anemia), the MPV may be low even though there is thrombocytopenia.

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# End of CBC - 1

**This concludes the Mean Platelet Volume section and Part 1 of the study module, "The Complete Blood Cell Count (CBC)".**

**Click on Hemogram Menu to review a section.**

**OR**

**Click on** 

**to quit CBC – Part 1**

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# THE END

The following are additional exercises related to the CBC:

| | |
|---|---|
| CBC – Part 2 | WBC differential & blood morphology |
| CBC – Part 3 | RBC morphology & platelet estimate |
| CBC – Part 4 | Post-test |

quit