11. Disturbances of Acid-Base Balance

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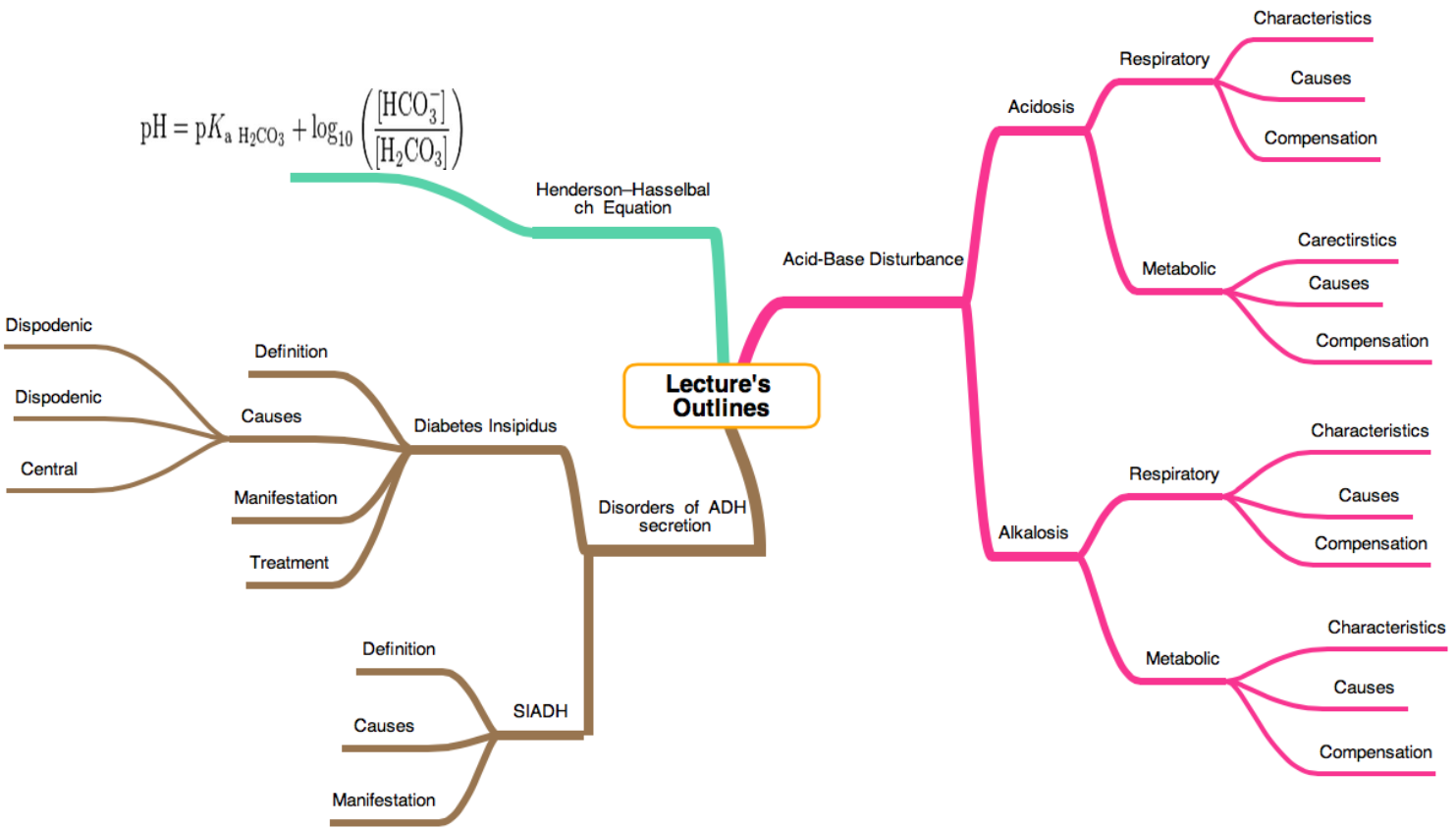
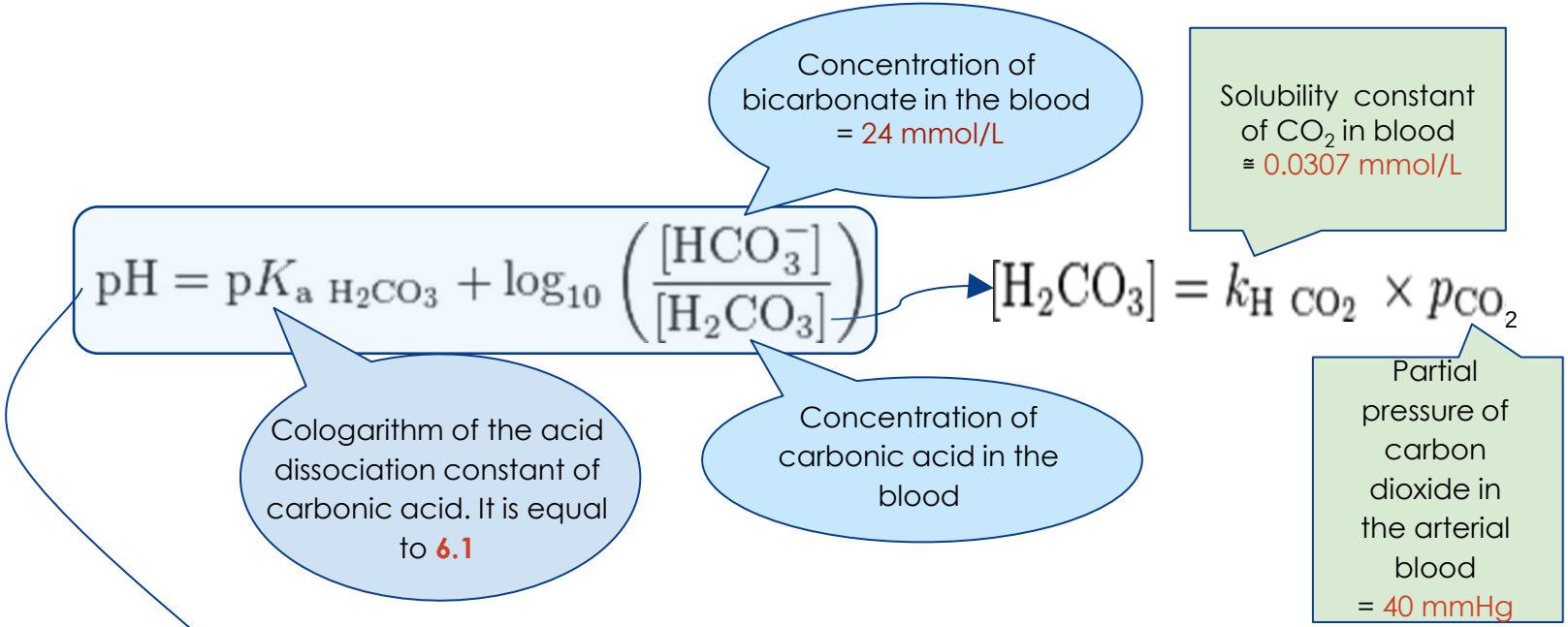


The Henderson–Hasselbalch Equation

It can be applied to relate the pH of blood to constituents of bicarbonate buffer system.



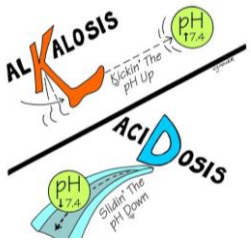
In health, pH = 7.4

In the previous lecture, we have described the mechanism by which the kidneys secrete H+ and reabsorb HCO_3- . Now we can explain how the kidneys readjust the pH of the extracellular fluid when it becomes **abnormal.**

Disturbances of Acid-Base Balance

- Referring to the **Henderson-Hasselbalch equation,** we can see that acidosis occurs when the ratio of HCO_3– to CO_2 in the extracellular fluid <u>decreases, thereby decreasing pH.</u>

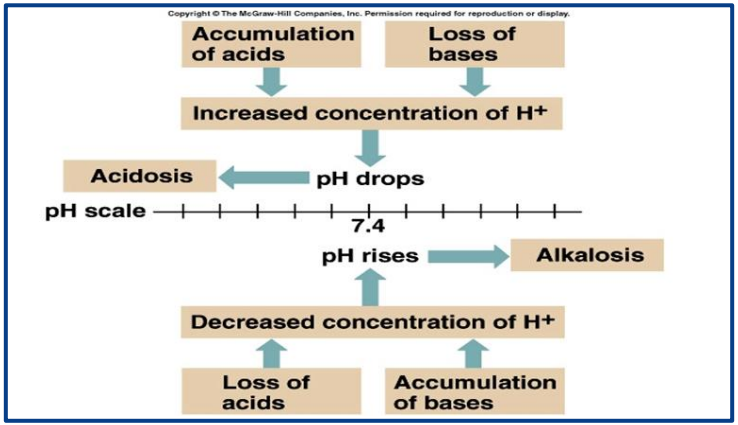
The ratio (pH) ↓ of ↓ HCO_3– → **Metabolic Acidosis**

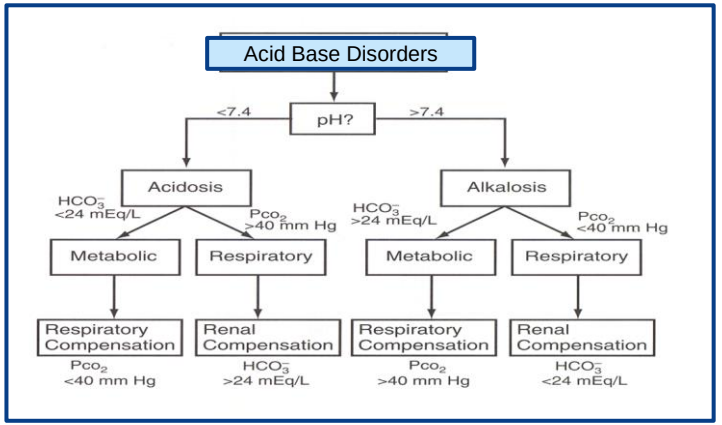


The ratio (pH)↓ of ↑ PCO_2 → **Respiratory Acidosis**

The opposite occurs in **alkalosis.**

So, pH problems due to a **respiratory disorder** result in **RESPIRATORY** acidosis or alkalosis.
and pH problems arising from acids or bases of **a non-CO_2 origin** result in **METABOLIC** acidosis or alkalosis





Rates of Correction

Buffers, take seconds.

Respiratory mechanisms, take several minutes to hours.

Renal mechanisms, may take several hours to days.

Respiratory Acidosis

✧ **Characterised by :**
Reduction in pH, an ↑ in ECF H^+ concentration, and an ↑ in Pco_2 (above 45 mmHg)

✧ **Causes:** (results from ↓ ventilation and ↑ Pco_2)

- Depression of respiratory centres in brain by drugs or head trauma.
- Paralysis of respiratory or chest muscles.
- Emphysema/COPD.
- Pulmonary edema.

✧ **Compensation:**

1- Renal: By increase in plasma HCO_3^- caused by the addition of *new* HCO_3^- to the ECF by the kidneys. The rise in HCO_3^-- helps offset the increase in Pco_2 , thereby returning the plasma pH toward normal.

2-Buffers: To continue secretion of H+[1] the excess H+ has to be buffered (phosphate & ammonia), at the same time new molecules of HCO3- will be formed and pass into the blood.

Respiratory Alkalosis

✧ **Characterised by :**
Increase in pH, an ↓ in ECF H^+ concentration, and an ↓ in Pco_2 (below 45 mmHg)

✧ **Cause:** (results from ↑ ventilation and ↓ Pco_2)

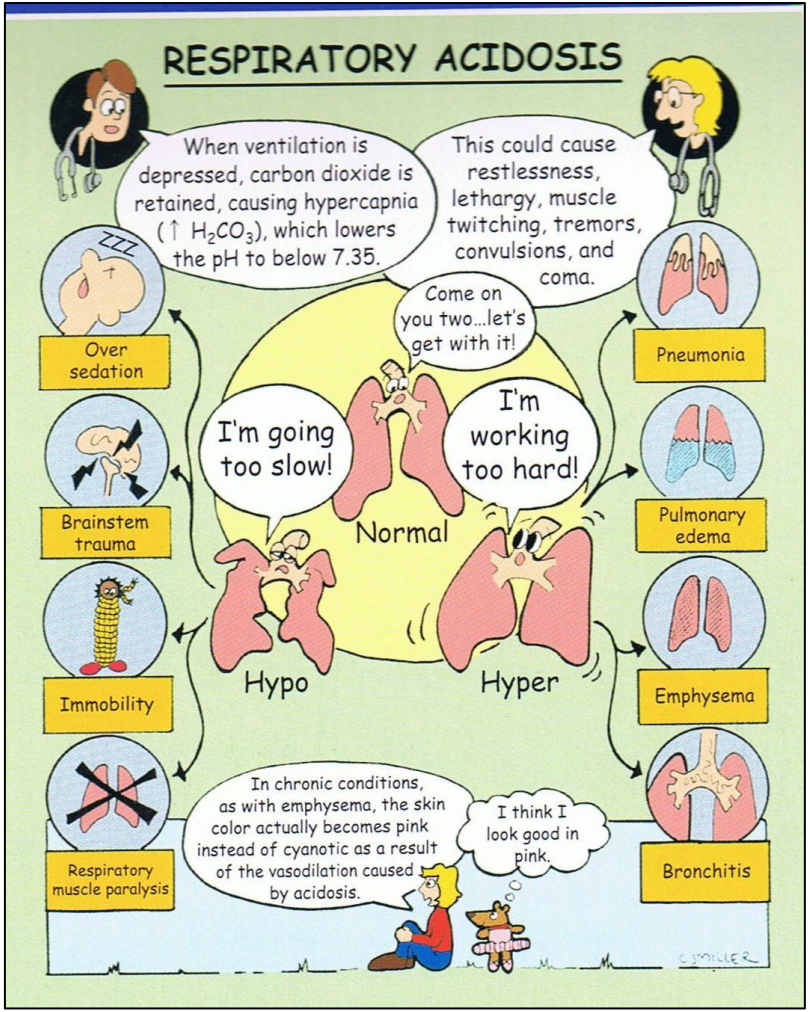
- Conditions that stimulate respiratory centres leads to a decrease in plasma Pco_2 , caused by hyperventilation.
- Oxygen deficiency at high altitudes.

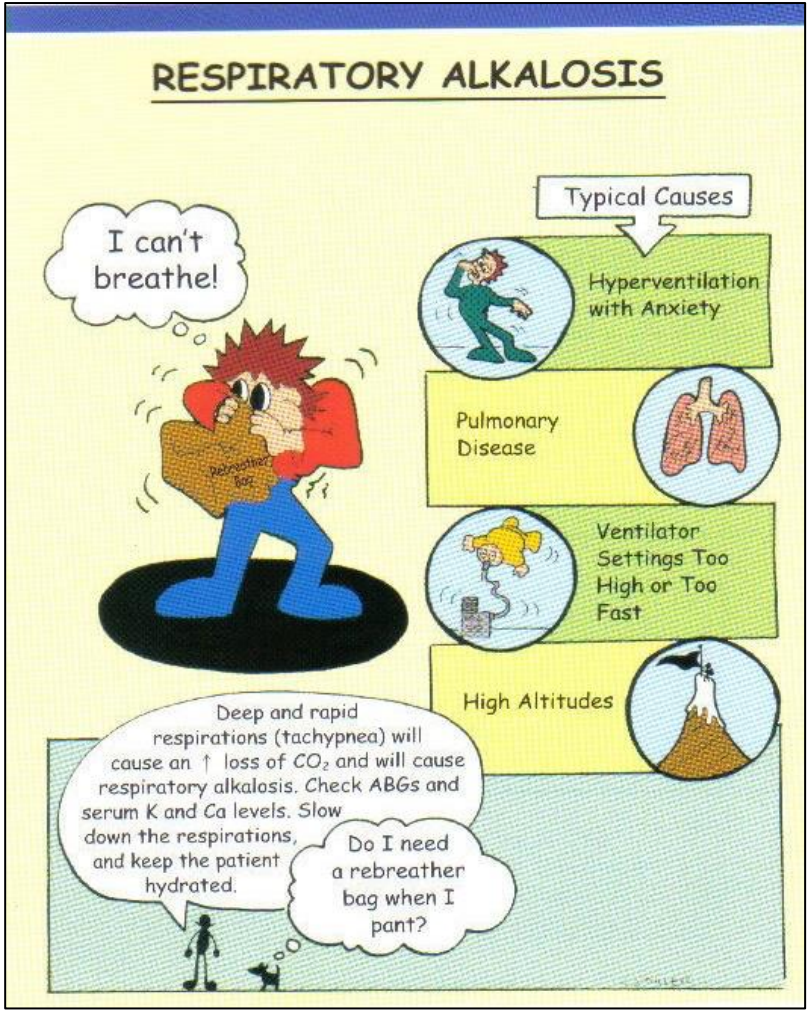
✧ **Compensation:**

1-Renal: By reduction in plasma HCO_3^-- concentration, caused by increased renal *excretion of* HCO_3^--(in an attempt to reduce plasma HCO3- concentration toward normal.)

Primary cause "color code"

1: The lower limit of tubular fluid pH that allows H+ secretion is 4.5.


RESPIRATORY ACIDOSIS
When ventilation is depressed, carbon dioxide is retained, causing hypercapnia (↑ H_2CO_3), which lowers the pH to below 7.35.
This could cause restlessness, lethargy, muscle twitching, tremors, convulsions, and coma.
Come on you two...let's get with it!
I'm going too slow!
I'm working too hard!
Normal
Hypo
Hyper
Over sedation
Brainstem trauma
Immobility
Respiratory muscle paralysis
Pneumonia
Pulmonary edema
Emphysema
Bronchitis
In chronic conditions, as with emphysema, the skin color actually becomes pink instead of cyanotic as a result of the vasodilation caused by acidosis.
I think I look good in pink.


RESPIRATORY ALKALOSIS
I can't breathe!
Typical Causes
Hyperventilation with Anxiety
Pulmonary Disease
Ventilator Settings Too High or Too Fast
High Altitudes
Deep and rapid respirations (tachypnea) will cause an ↑ loss of CO_2 and will cause respiratory alkalosis. Check ABGs and serum K and Ca levels. Slow down the respirations, and keep the patient hydrated.
Do I need a rebreather bag when I pant?

Metabolic Acidosis

✧ **Characterised by :**
Reduction in pH, an ↑ in ECF H^+ concentration, and ↓ in HCO_3^- (below 22 mEq/L)

✧ **Causes:**
- Loss of bicarbonate e.g. severe diarrhea.
- Hypoaldosteronism.
- Accumulation of acids e.g:.

*Diabetic ketosis.

*Failure of kidneys to excrete H+

*Drug toxicity e.g. salicylates.

✧ **Compensation:**

1- Respiratory: By *Increased ventilation rate*, which reduces Pco_2 .

2-Renal: By adding *new HCO_3^-* to the ECF,helps minimize the initial fall in ECF HCO_3^- concentration.

Metabolic Alkalosis

✧ **Characterised by :**
Increaes in pH, an ↑ in ECF H^+ concentration, and ↑ in HCO_3^- (above 27 mEq/L)

✧ **Causes:**
- Excess vomiting = loss of stomach acid.
- Excessive use of alkaline drugs.
- Certain diuretics.
- Endocrine disorders: Hyperaldosteronism.
- Severe dehydration.

✧ **Compensation:**

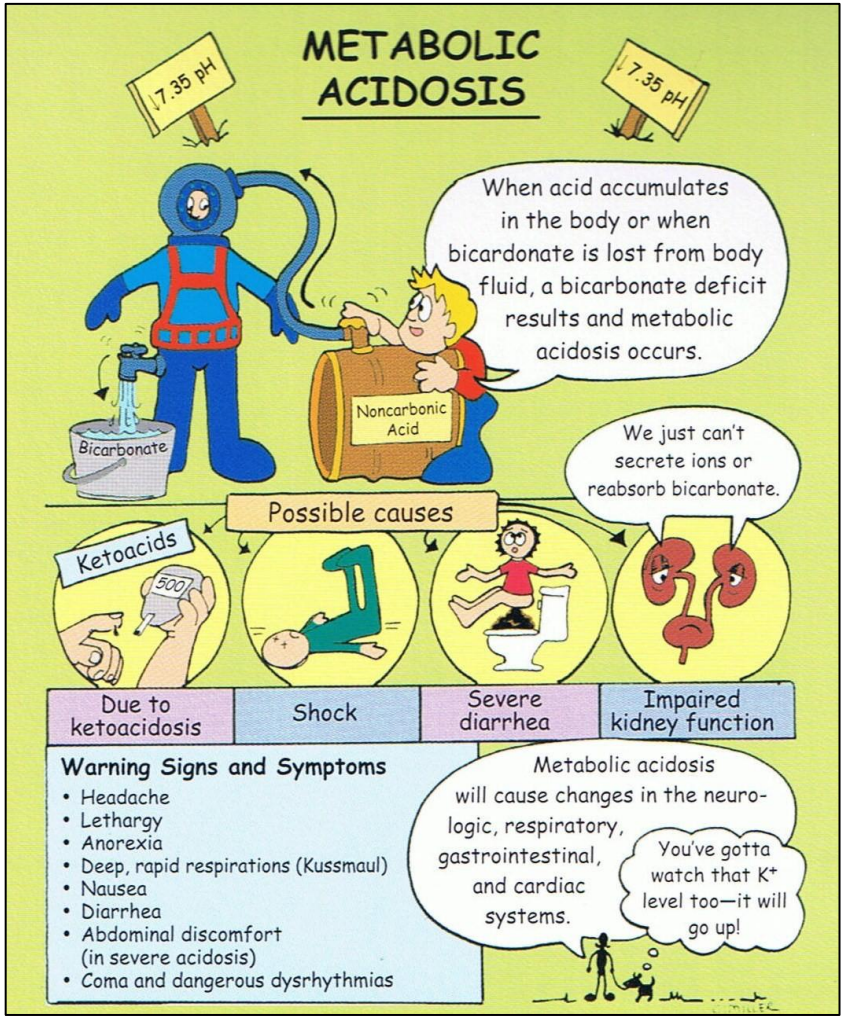
1- Respiratory: By *Decreased ventilation rate*, which raises Pco_2 .

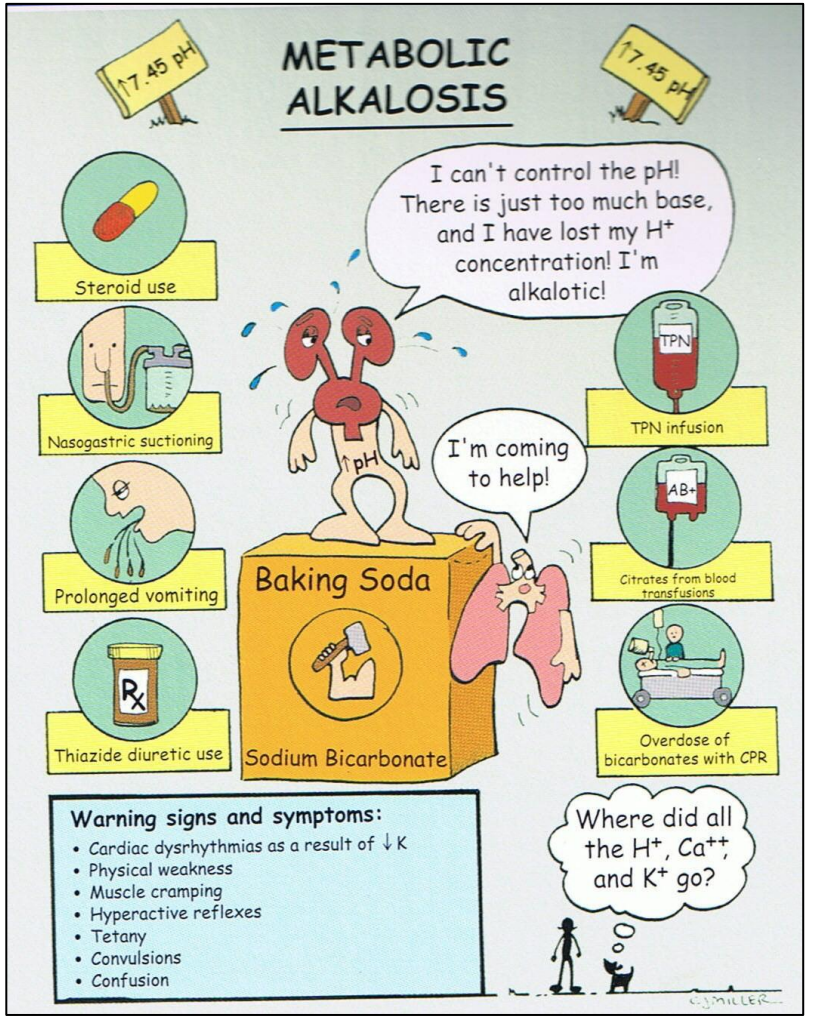
2-Renal: By increasing *HCO_3^- renal excretion*, which helps compensate for the initial rise in ECF HCO_3^- concentration

- Does arterial Pco_2 remain unchanged in these cases? NO!

Remember, plasma Pco_2 changes during metabolic acidosis / alkalosis are a *result of*, not *cause of*, compensatory reflex responses to non-respiratory abnormalities.

Primary cause "color code"


METABOLIC ACIDOSIS
↓7.35 pH
↓7.35 pH
When acid accumulates in the body or when bicardonate is lost from body fluid, a bicarbonate deficit results and metabolic acidosis occurs.
Bicarbonate
Noncarbonic Acid
We just can't secrete ions or reabsorb bicarbonate.
Possible causes
Ketoacids
Due to ketoacidosis
Shock
Severe diarrhea
Impaired kidney function
Warning Signs and Symptoms
• Headache
• Lethargy
• Anorexia
• Deep, rapid respirations (Kussmaul)
• Nausea
• Diarrhea
• Abdominal discomfort (in severe acidosis)
• Coma and dangerous dysrhythmias
Metabolic acidosis will cause changes in the neuro-logic, respiratory, gastrointestinal, and cardiac systems.
You've gotta watch that K+ level too—it will go up!


METABOLIC ALKALOSIS
↑7.45 pH
↑7.45 pH
I can't control the pH! There is just too much base, and I have lost my H+ concentration! I'm alkalotic!
Steroid use
Nasogastric suctioning
Prolonged vomiting
Thiazide diuretic use
↑pH
I'm coming to help!
Baking Soda
Sodium Bicarbonate
TPN
TPN infusion
AB+
Citrates from blood transfusions
Overdose of bicarbonates with CPR
Warning signs and symptoms:
• Cardiac dysrhythmias as a result of ↓K
• Physical weakness
• Muscle cramping
• Hyperactive reflexes
• Tetany
• Convulsions
• Confusion
Where did all the H+, Ca++, and K+ go?

	pH	H^+	Pco_2	HCO_3^-
Normal	7.4	40 mEq/L	40 mm Hg	24 mEq/L
Respiratory acidosis	↓	↑	↑↑	↑
Respiratory alkalosis	↑	↓	↓↓	↓
Metabolic acidosis	↓	↑	↓	↓↓
Metabolic alkalosis	↑	↓	↑	↑↑

Example

A patient is in intensive care because he suffered a severe myocardial infarction 3 days ago. The lab reports the following values from an arterial blood sample: ***(pH =7.21, PCO2= 42, HCO3- = 12)***

List the condition: acidosis or alkalosis, metabolic or respiratory, compensated or uncompensated?

Answer:

Metabolic acidosis, uncompensated

(why we say uncompensated? because of the *no change* in plasma Pco_2)

More Examples

pH	$PaCO_2$	PaHCO3	Condition
★ 7.21 ↓	**32** ↓	**14** ↓↓	**Metabolic Acidosis, Compensated.**
★ 7.5 ↑	26 ↓↓	21 ↓	**Respiratory Alkalosis, Compensated.**
★ 7.36 ↓	54 ↑↑	32 ↑	**Respiratory Acidosis, Compensated.**

ALWAYS KEEP THIS PICTURE IN MIND

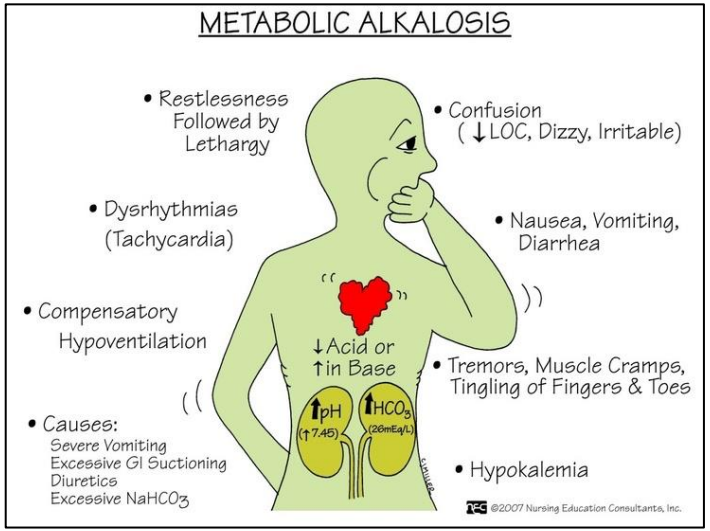
	pH	H^+	Pco_2	HCO_3^-
Normal	7.4	40 mEq/L	40 mm Hg	24 mEq/L
★ Respiratory acidosis	↓	↑	↑↑	↑
★ Respiratory alkalosis	↑	↓	↓↓	↓
★ Metabolic acidosis	↓	↑	↓	↓↓
Metabolic alkalosis	↑	↓	↑	↑↑

Disorders of ADH secretion

	Diabetes Insipidus	Syndrome of inappropriate ADH secretion
Definition	Deficient ADH secretion or reduced response to it .	Non- physiological or excess release of ADH .
Causes	**1- Central :** damage to the pituitary gland disrupts the storage and release of ADH . **2- Nephrogenic :** kidneys are unable to respond to ADH, due to drugs (lithium), chronic disorders such as polycystic kidney disease, sickle cell disease, kidney failure, partial blockage of ureter , genetic disorders. **3- Dispodenic :** defect or damage to the thirst mechanism which is located in hypothalamus, results in increase thirst and fluid uptake which suppress ADH secretion.	1- Infections : HIV, Meningitis, encephalitis, abscess. 2- vascular : subarachnoid or subdural hemorrhage. 3- Neoplasm 4- Post-pituitary surgery, multiple sclerosis, psychosis, BMT or stem cell transplant. 5- Drugs : chemotherapeutic, antidepressants, Bromocriotine (dopamine agonist). 6- Pulmonary diseases. 7- Idiopathic
Manifestation	Polyuria - polydipsia (excess thirst) - Diluted urine (low fixed specific gravity) -Dehydration (when patients don't drink enough). In DM : urine is concentrated due to hyperglycemia.	- Oliguria - hyponatremia (lethargy , apathy, disorientation, muscle cramps, anorexia ,agitation) when Na conc. Is lower than 110 mEq\L (seizures, bulbar palsies, hypothermia, stupor, coma) - water toxicity (nausea, vomiting, personality changes, confusion) –
Treatment	For central causes : synthetic hormone (desmopressin) can be taken orally or injection. For Nephrogenic causes : desmopressin is not effective, and Moduretic is given . In these two types patients should drink fluid only when thirsty, not at other times. For Dispodenic causes: no effective treatment is found yet .	

	Respiratory Acidosis	Respiratory Alkalosis	Metabolic Acidosis	Metabolic Alkalosis
	Carbonic acid (CO_2) excess> 40	Decreased CO_2 (Hyperventilation)	bicarbonate(HCO_3) < 24 mEq/L	Bicarbonate(HCO_3) excess >24mEq/L
causes	-Depression of respiratory center in brain by drugs or head trauma -Paralysis of respiratory or chest muscles -Emphysema/COPD. -Pulmonary edema.	Oxygen deficiency at high altitudes.	- Loss of bicarbonate e.g. severe diarrhea. -Hypoaldosteronism. -Accumulation of acids e.g:. 1-Diabetic ketosis . 2-Failure of kidneys to excrete H+ 3-Drug toxicity e.g. salicylates.	-Excess vomiting = loss of stomach acid -Excessive use of alkaline drugs -Certain diuretics -Endocrine disorders: (Hyperaldosteronism). (cause secretion of H+) -Severe dehydration
features	- Reduction in pH - Increase in $PaCO_2$	-Increase in pH. - Decrease in $PaCO_2$	-decrease in pH. -primary abnormality is a decrease in plasma HCO_3.	-Increase plasma pH - rise in HCO_3.
compensation	1-Buffer. **2-Renal:** Increase new generation $HCO_3 \rightarrow$ increase secretion of H+	1- Buffer **2- Renal** renal excretion of HCO_3 to reduce plasma HCO_3 to normal	1-Buffer **2-Respiratory:** hyperventilation (reduces $PaCO_2$). 3- Renal (if kidney normal): new bicarbonate excretes more H+.	1- Buffer **2-Respiratory:** (hypoventilation) $\rightarrow$ Raises CO_2.

Summary


METABOLIC ALKALOSIS
• Restlessness Followed by Lethargy
• Confusion (↓LOC, Dizzy, Irritable)
• Dysrhythmias (Tachycardia)
• Nausea, Vomiting, Diarrhea
• Compensatory Hypoventilation
↓Acid or ↑in Base
• Tremors, Muscle Cramps, Tingling of Fingers & Toes
• Causes:
Severe Vomiting
Excessive GI Suctioning
Diuretics
Excessive NaHCO3
↑pH (↑7.45)
↑HCO3 (28mEq/L)
• Hypokalemia
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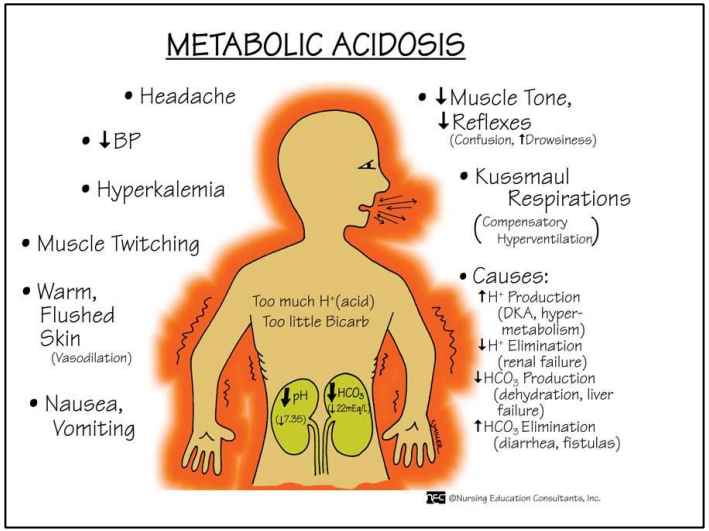
METABOLIC ACIDOSIS
• Headache
• ↓BP
• Hyperkalemia
• Muscle Twitching
• Warm, Flushed Skin (Vasodilation)
• Nausea, Vomiting
• ↓Muscle Tone, ↓Reflexes (Confusion, ↑Drowsiness)
• Kussmaul Respirations (Compensatory Hyperventilation)
• Causes:
↑H+ Production (DKA, hyper-metabolism)
↓H+ Elimination (renal failure)
↓HCO3 Production (dehydration, liver failure)
↑HCO3 Elimination (diarrhea, fistulas)
Too much H+(acid)
Too little Bicarb
↓pH (↓7.35)
↓HCO3 (↓22mEq/L)
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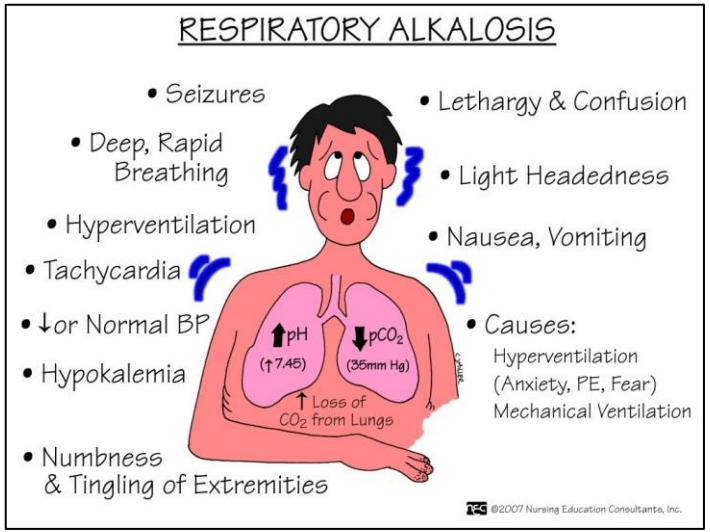
RESPIRATORY ALKALOSIS
• Seizures
• Deep, Rapid Breathing
• Hyperventilation
• Tachycardia
• ↓or Normal BP
• Hypokalemia
• Numbness & Tingling of Extremities
• Lethargy & Confusion
• Light Headedness
• Nausea, Vomiting
• Causes:
Hyperventilation (Anxiety, PE, Fear)
Mechanical Ventilation
↑pH (↑7.45)
↓pCO2 (35mm Hg)
↑ Loss of CO2 from Lungs
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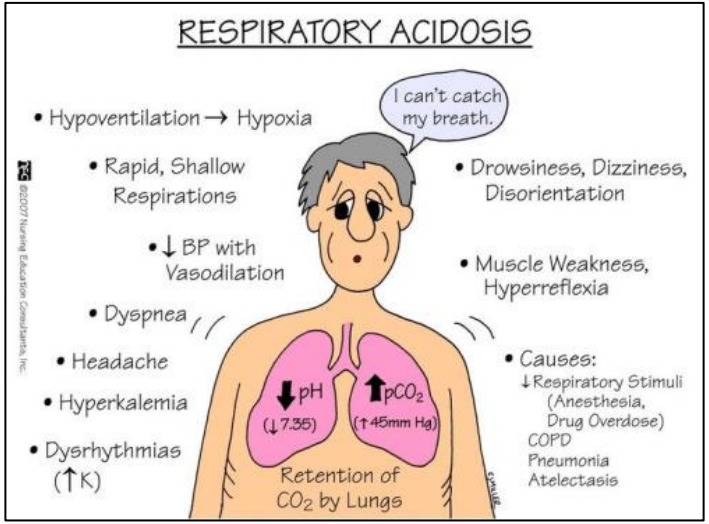
RESPIRATORY ACIDOSIS
I can't catch my breath.
• Hypoventilation → Hypoxia
• Rapid, Shallow Respirations
• ↓ BP with Vasodilation
• Dyspnea
• Headache
• Hyperkalemia
• Dysrhythmias (↑K)
• Drowsiness, Dizziness, Disorientation
• Muscle Weakness, Hyperreflexia
• Causes:
↓Respiratory Stimuli (Anesthesia, Drug Overdose)
COPD
Pneumonia
Atelectasis
↓pH (↓7.35)
↑pCO2 (↑45mm Hg)
Retention of CO2 by Lungs
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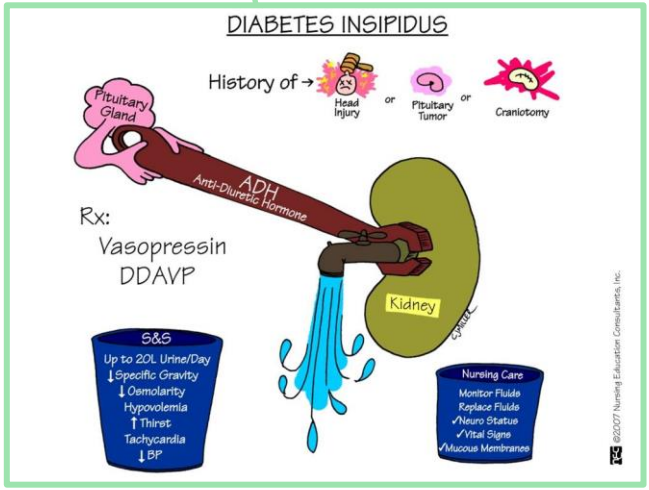
Summary

Summary

- Diabetes Insipidus (DI)
  - ADH Disorders
    - SIADH
      - Characteristics:
        - Fluid Retention.
        - Serum Hypo-osmolarity.
        - Dilutional Hyponatraemia.
        - Hypchloremia.
        - Concentrated Urine in the Presence of Normal or Increased Intravascular Volume.
        - Normal Renal Function.
      - Signs/Symptoms:
        - Decreased / Low Urine Output.
        - Symptoms of Hyponatraemia.
        - Symptoms of Water Toxicity.
        - If Na < 110 mEq/L.
  - Types:
    - Central DI
      - Results from damage to the pituitary gland.
      - Treatment: Desmopressin.
    - Nephrogenic DI
      - Results when the kidneys are unable to respond to ADH.
      - Treatment: Moduretic.
    - Dispodenic DI
      - Caused by a defect in or damage to the thirst mechanism
      - No Treatment.



1- What is the normal arterial blood PH:
A. 7.4
B. 7.35
C. 6

2- Decrease in HCO_3 concentration is termed as:
A. Respiratory acidosis
B. Metabolic acidosis
C. Metabolic alkalosis

3- What is the initial cause of respiratory acidosis:
A. Decrease in PCO_2
B. Decrease in HCO_3
C. Increase in PCO_2

4- What is lower limit of pH at which a person can live for more than a few hours is ..... and the upper limit is about.....:
A. 6,.8 , 8
B. 7 , 8.3
C. 7.5 , 9

5- 5.which of these mechanisms takes hours or several days to regulate acid base balance:
A. Buffer system
B. Respiratory systems
C. Kidneys

6- Which of the following is not a symptom of Diabetes insipidus:
A. Polyuria
B. Polydepsia
C. Concentrated urine

7- Results from damage to the pituitary gland?
A. Central DI
B. Nephrogenic DI
C. Dipsogenic DI

8- During Nephrogenic DI treatment the patient should drink a lot of water.
A. True B. False

9- in Dispodenic DI urine output is?
A.Decrease
B. Increase
C. Constant

10- Syndrome of inappropriate ADH secretion could be caused by?
A. Encephalitis
B. Hemorrhage
C. Chemotherapy
D. All of them

1.A
2.B
3.C
4.A
5.C
6.C
7.A
8.B
9.B
10.D

MCQs

1- Mention the causes of metabolic alkalosis:
Excess vomiting = loss of stomach acid, Excessive use of alkaline drugs, Certain diuretics ,Endocrine disorders: Hyperaldosteronism, and Severe dehydration.

3- What will happen if there is metabolic acidosis (compensation) ?
*Respiratory: increased ventilation rate reduces PaCO2.
*Renal : adds new bicarbonate to the extracellular fluid and excretes more H+.

4- List the primary
*Acids taken with foods (such as proteins)
*Cellular metabolism produces CO_2.

5- Why the phosphate buffer is important in renal tubules?
*Becomes concentrated in the tubular fluid, so become powerful
*Its pKa = 6.8, which close to the pH in the tubular fluid of the distal nephron

6- How the kidney regulates blood pH?
By Reabsorption of filtered bicarbonate, Generation of new bicarbonate and Excretion of H+ .

6- A persons's arterial blood pH = 7.25, PCO_2 is 24 mmHg and HCO_3 is 10.2 mEq/L. Which might cause this pattern?
(it's metabolic acidosis) thus the causes may be : diaherra, Salicylate overdose and CRF.

1- Central DI is treated by?
Desmopressin

2- List 3 of Nephrogenic DI causes?
- Drugs—like lithium,
- Chronic disorders including polycystic kidney disease, sickle cell disease, kidney failure, partial blockage of the ureters, and inherited genetic disorders.

3- Why Dispodenic DI can't be treated with Desmopressin?
Because Desmopressin may decrease urine output but not thirst and fluid intake. This fluid overload can lead to water intoxication, a condition that lowers the concentration of sodium in the blood and can seriously damage the brain cells.

4- What are the Symptoms of water toxicity?
Nausea, vomiting, personality changes, confusion

5- List 3 of SIADH characteristics?
1-Serum hypo-osmolarity
2-dilutional hyponatraemia
3-hypchloremia

THANK YOU FOR CHECKING OUR WORK!

BEST OF LUCK

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