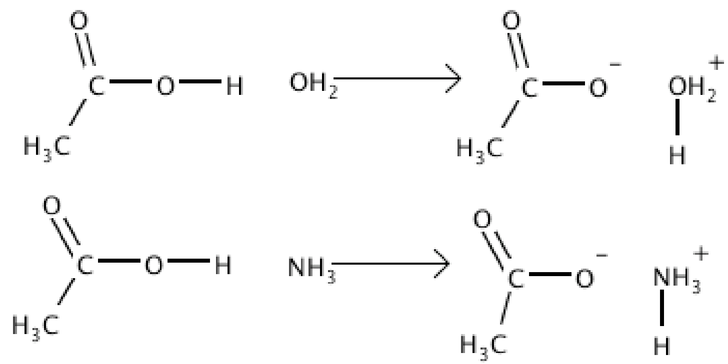
Blood Gases and Acid Base Balance

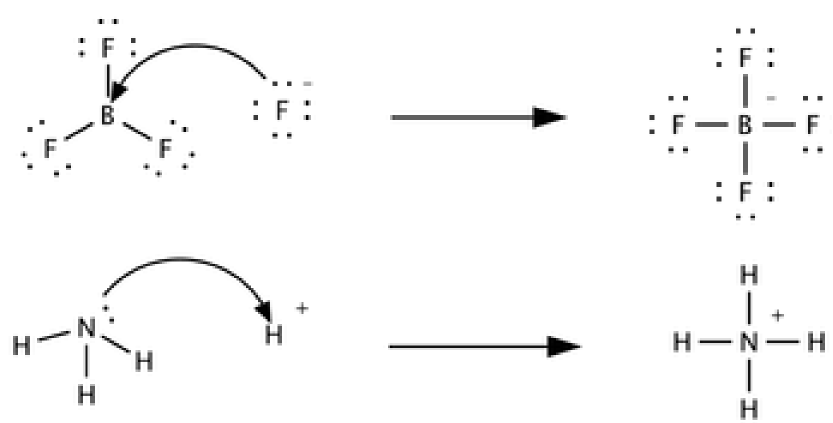
No, not that kind of gas.....

Acids and Bases

- An acid by any other name would be….?
  - Bronstead-Lowry
    - Proton donor

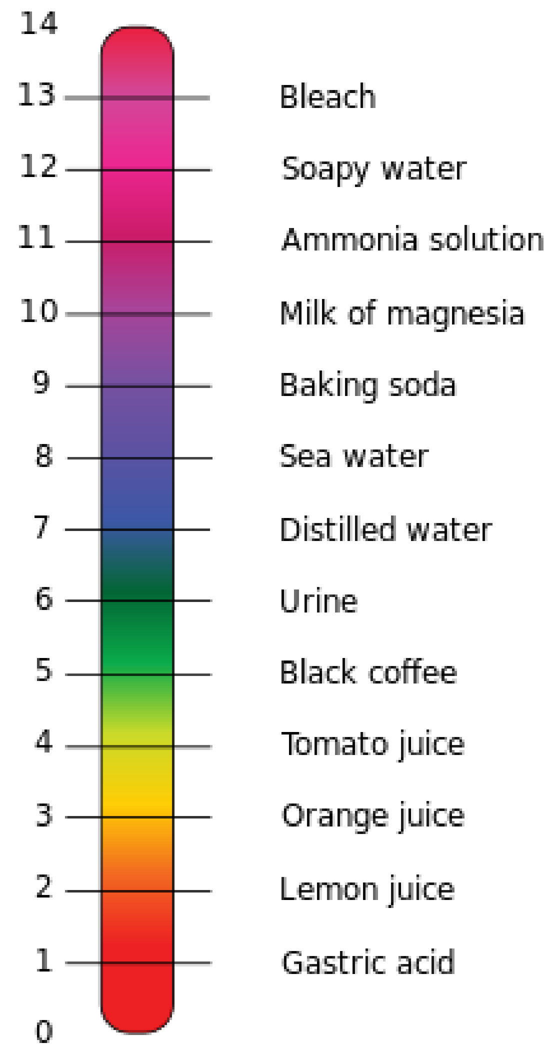


  - Lewis
    - Electron pair acceptor



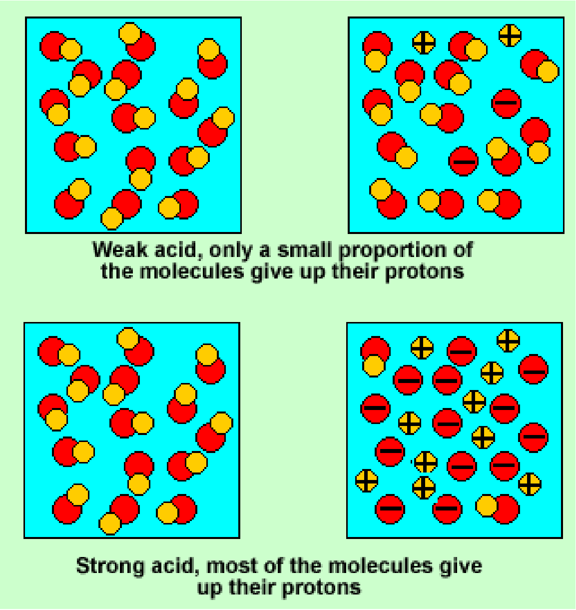
Acid and Bases

- Acid/Base parameter
  - pH scale
    - pH= -log[H^+]
    - 7 in the center is neutral
  - Ref. Range: 7.35-7.45
    - >7.45 = alkalosis
    - <7.35 = acidosis

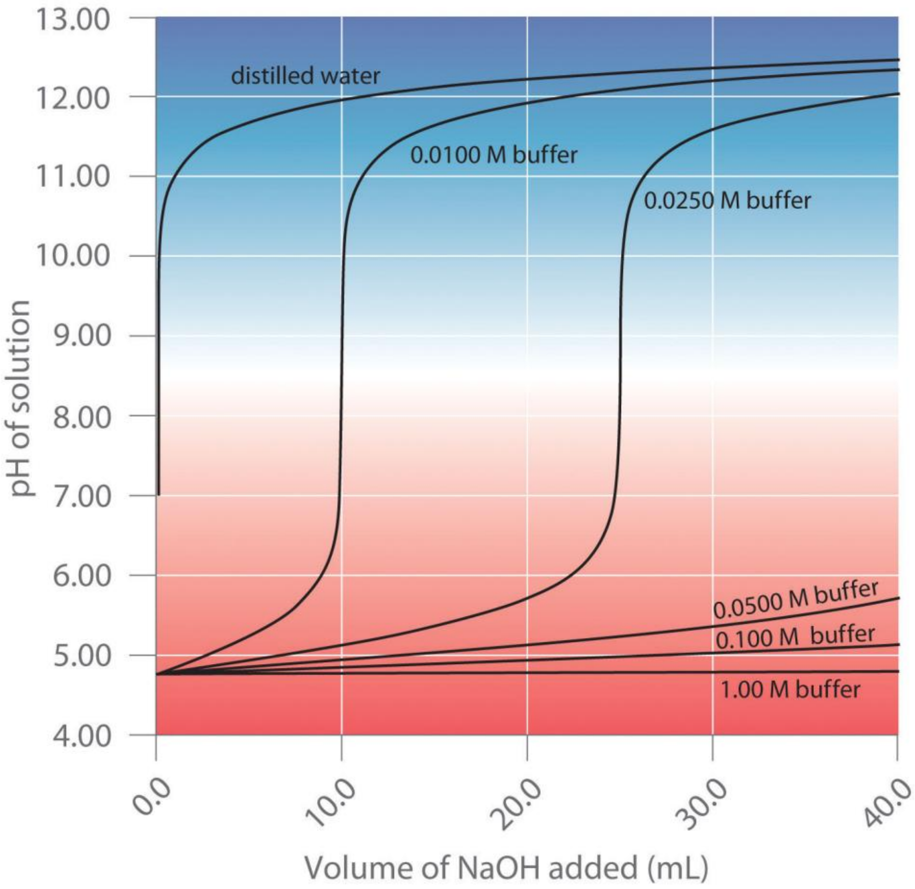


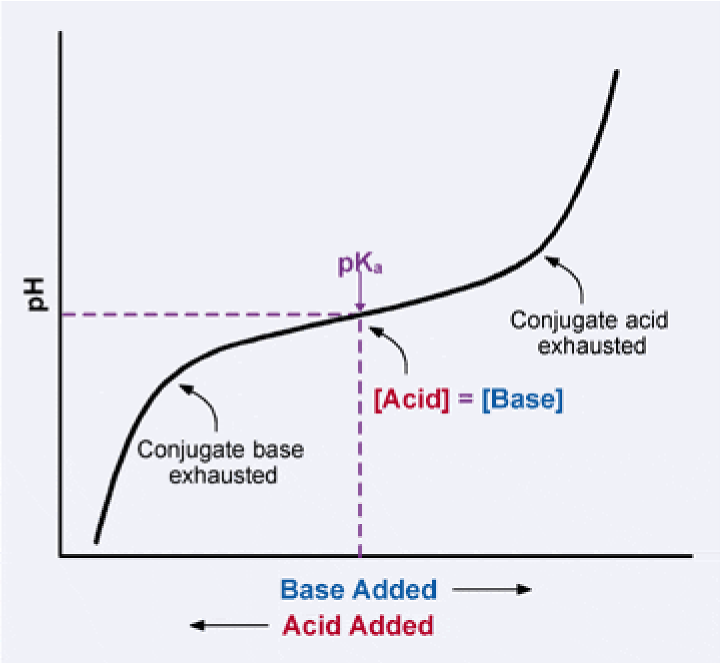
Acids and Bases

- Buffer systems
  - Weak acids or bases that act to resist changes in pH
    - WEAK = does not fully dissociate in solution



Acids and Bases

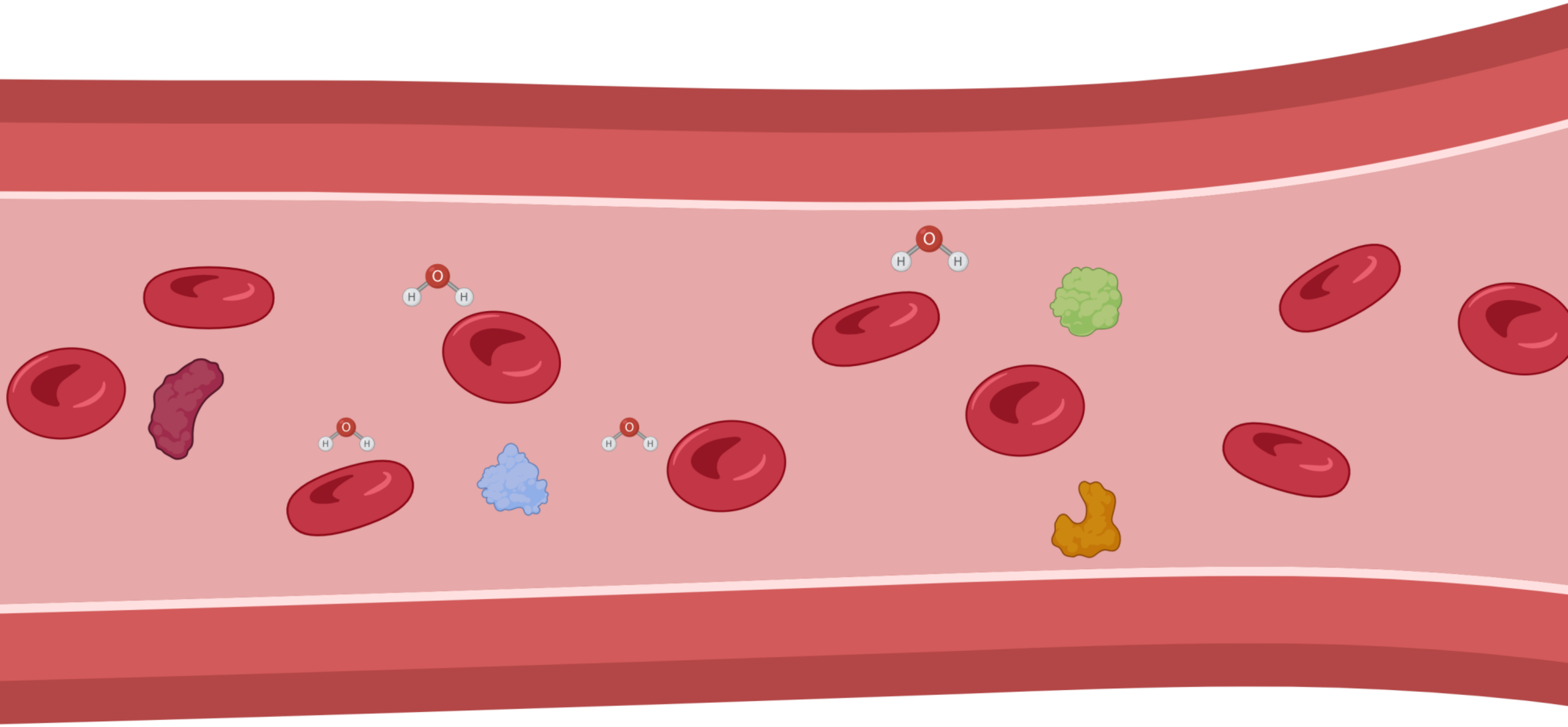




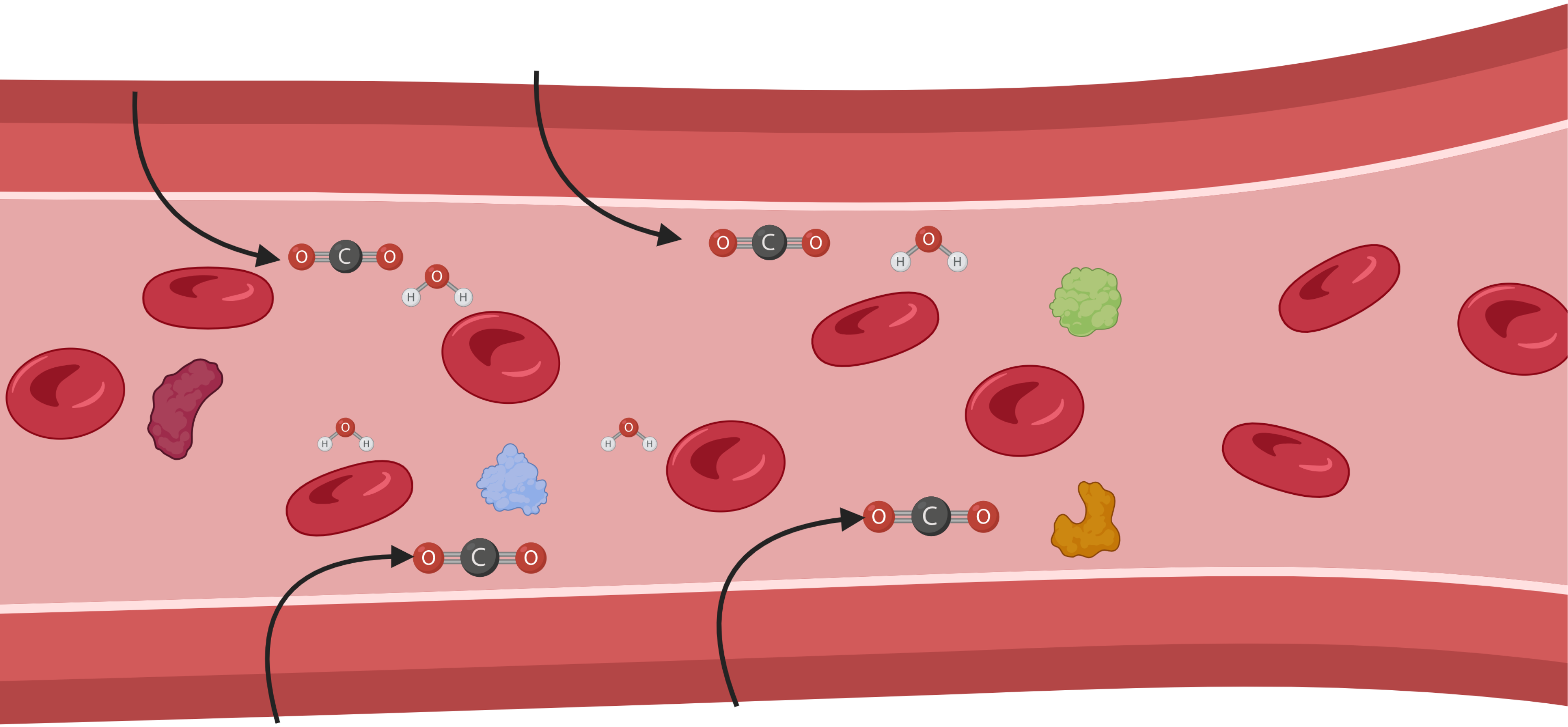
Biological Buffers

- Bicarbonate and Carbonic Acid H_2CO_3/HCO_3^-
  - CO2 formed by cells can:
    - Remain in plasma
      - Dissolve only a small amount
      - Hydrated to carbonic acid →Bicarb & H^+
      - Bind to proteins making carbamino compounds
    - Diffuse into RBCs
      - Dissolve only a small amount
      - More than half (65%) is hydrated, major buffer, transported to lungs without changing pH
      - Bind to hemoglobin forming carbamino compounds

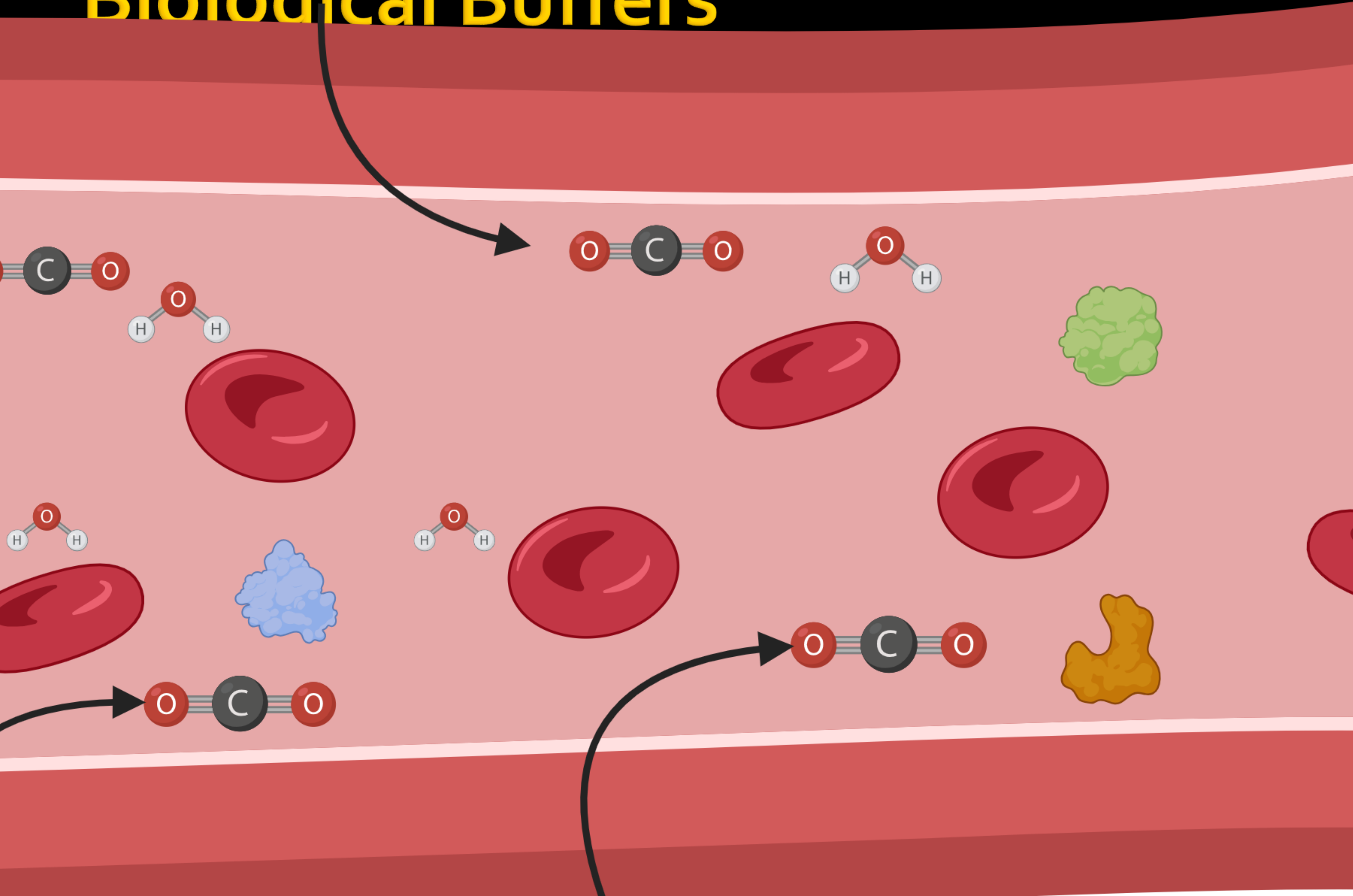
Biological Buffers



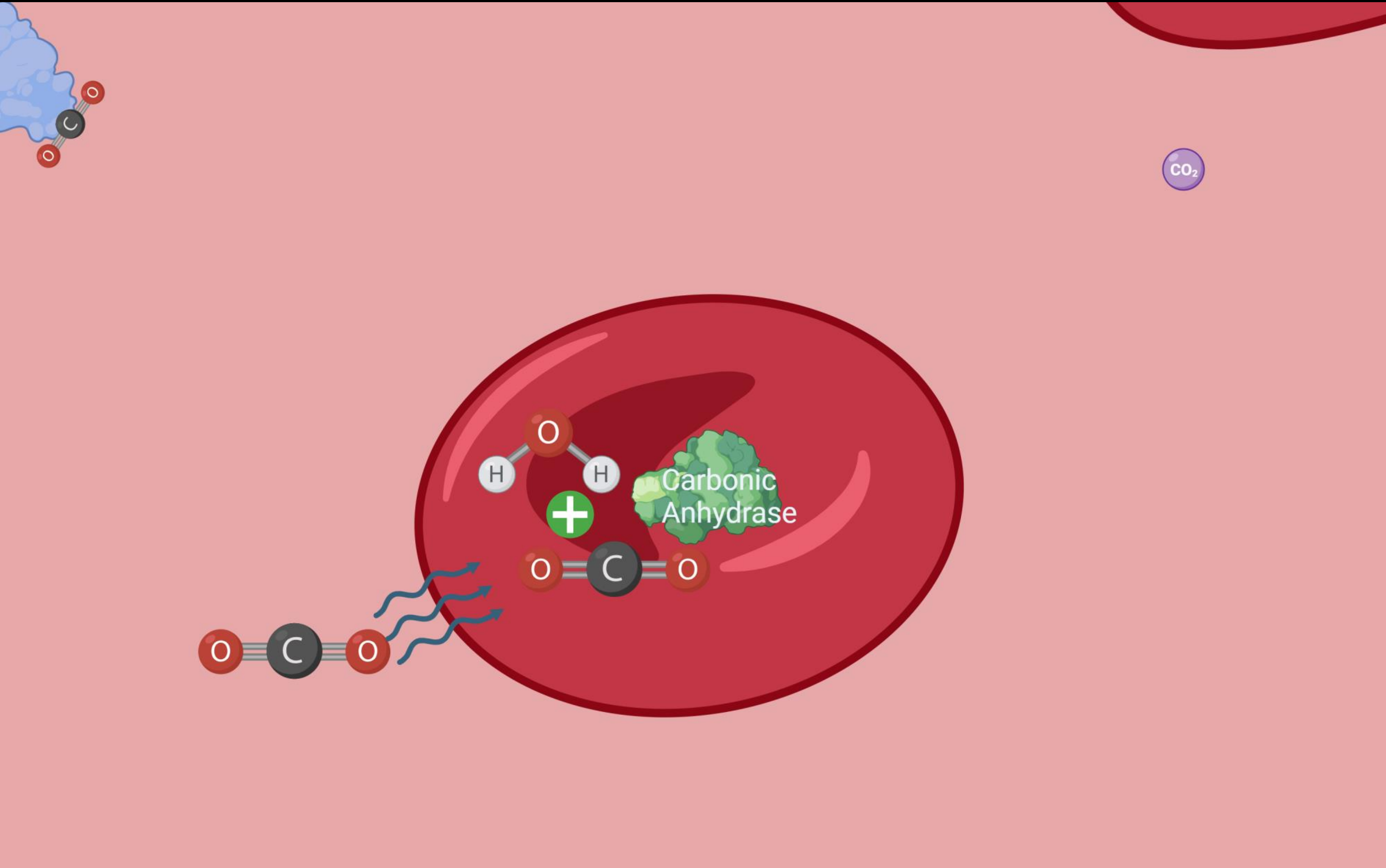
Biological Buffers



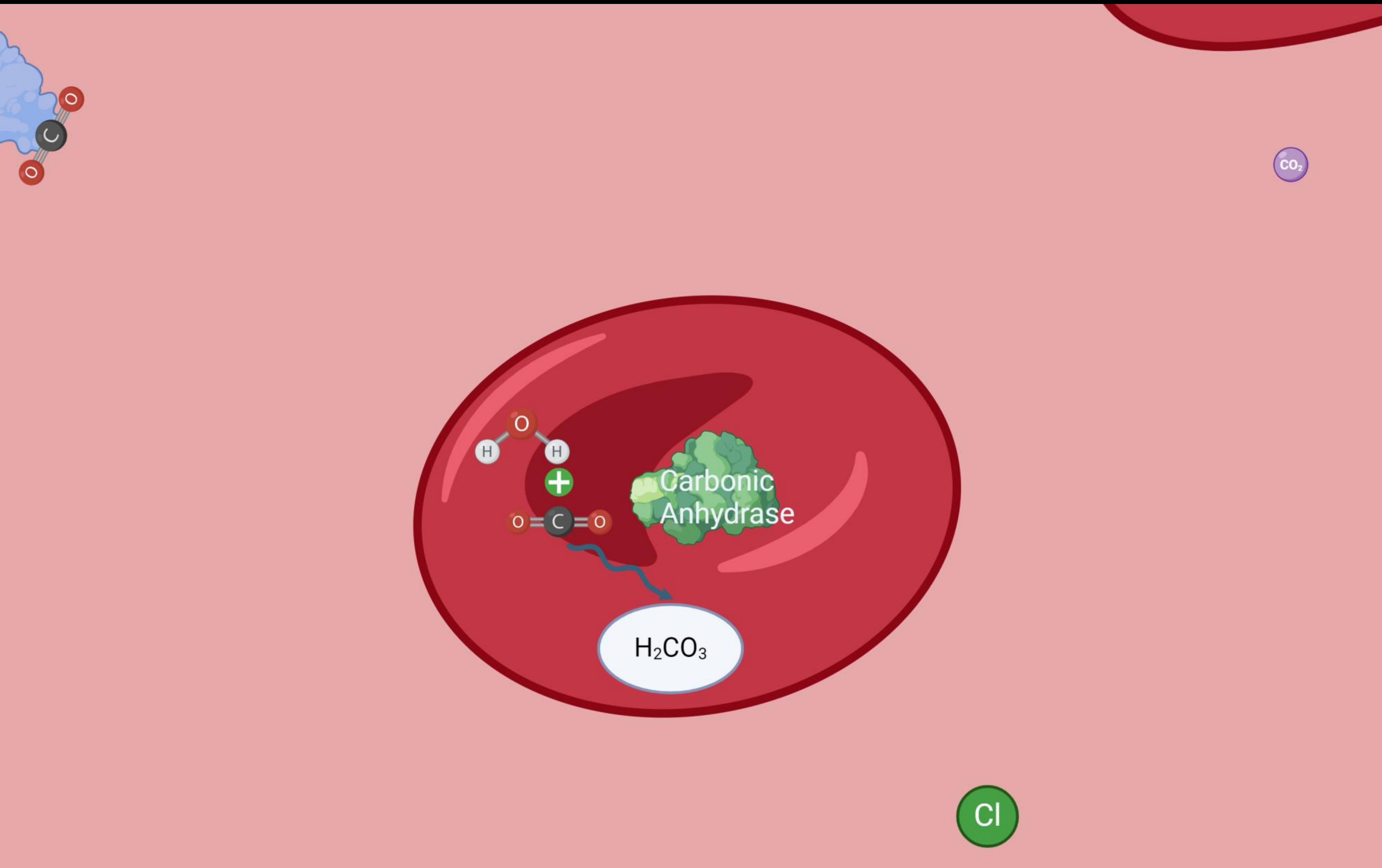
Biological Buffers



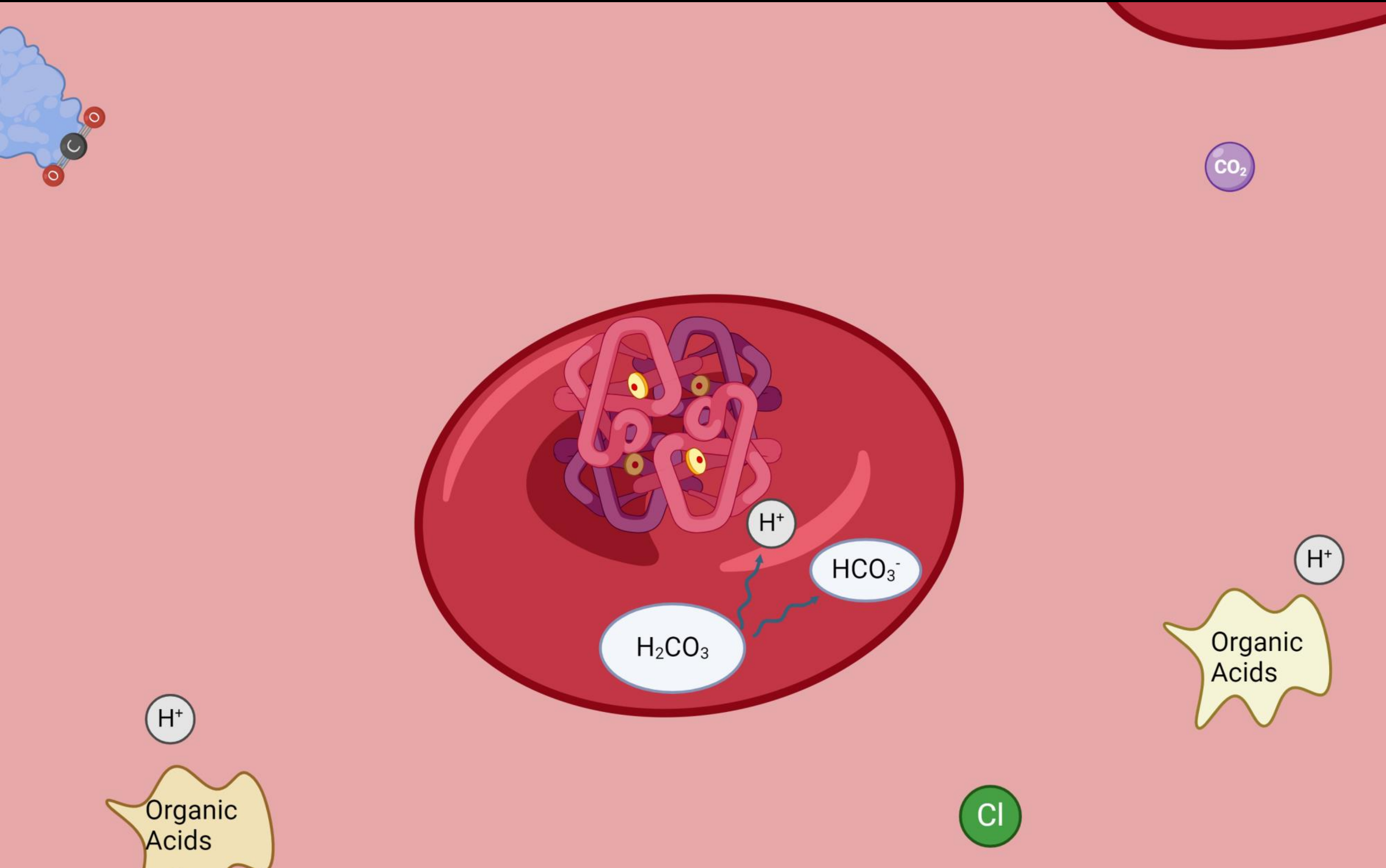
Biological Buffers



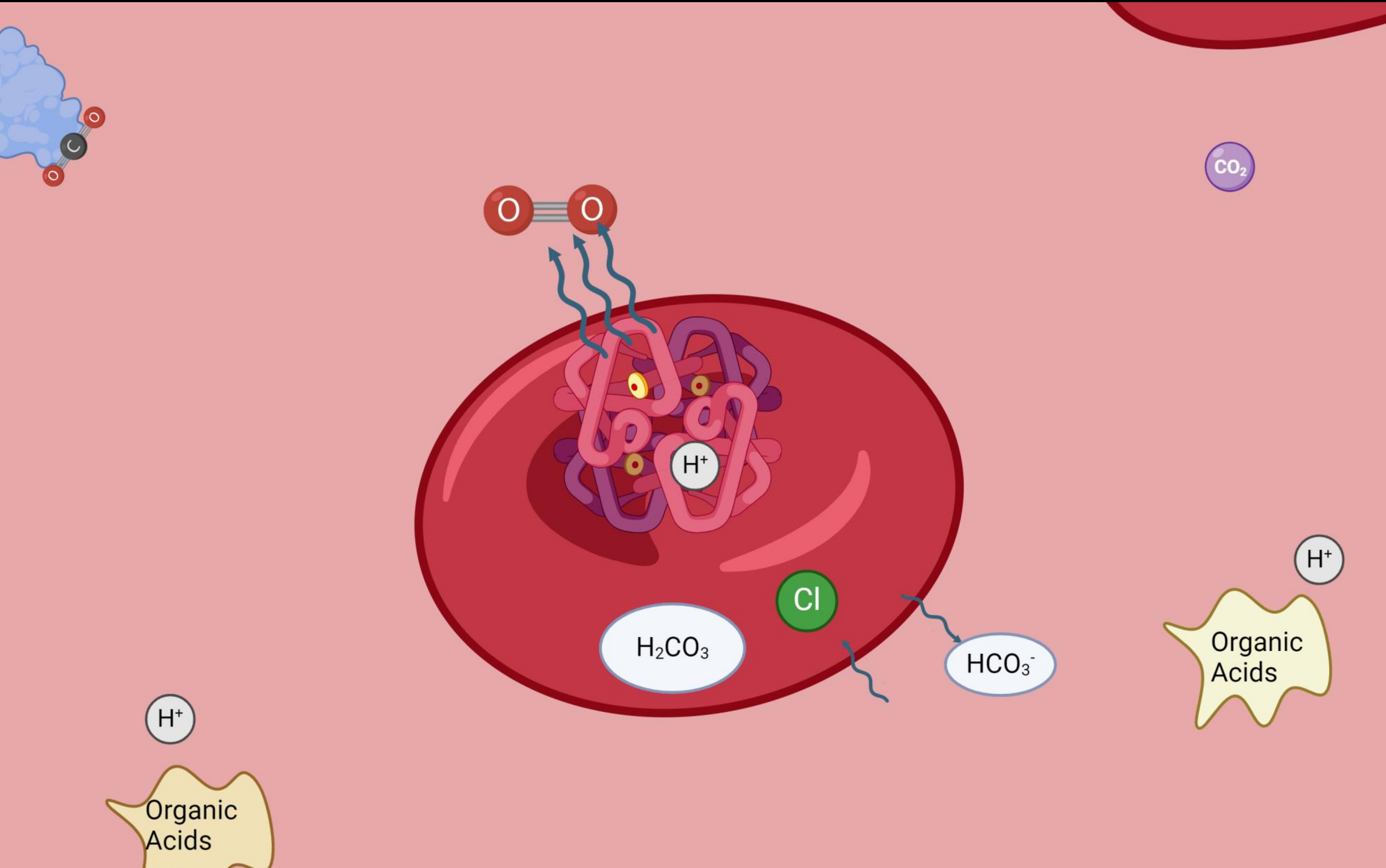
Biological Buffers



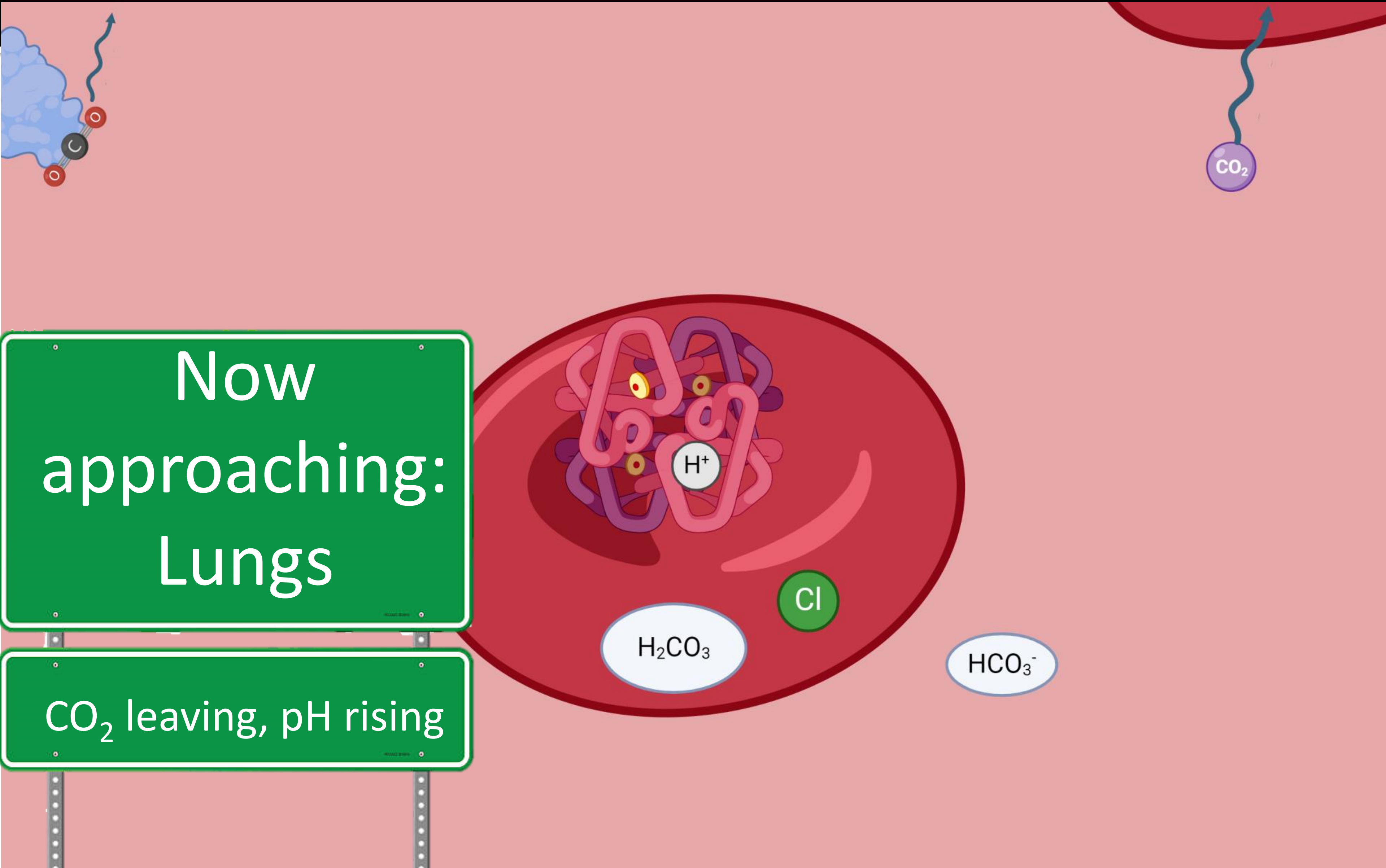
Biological Buffers



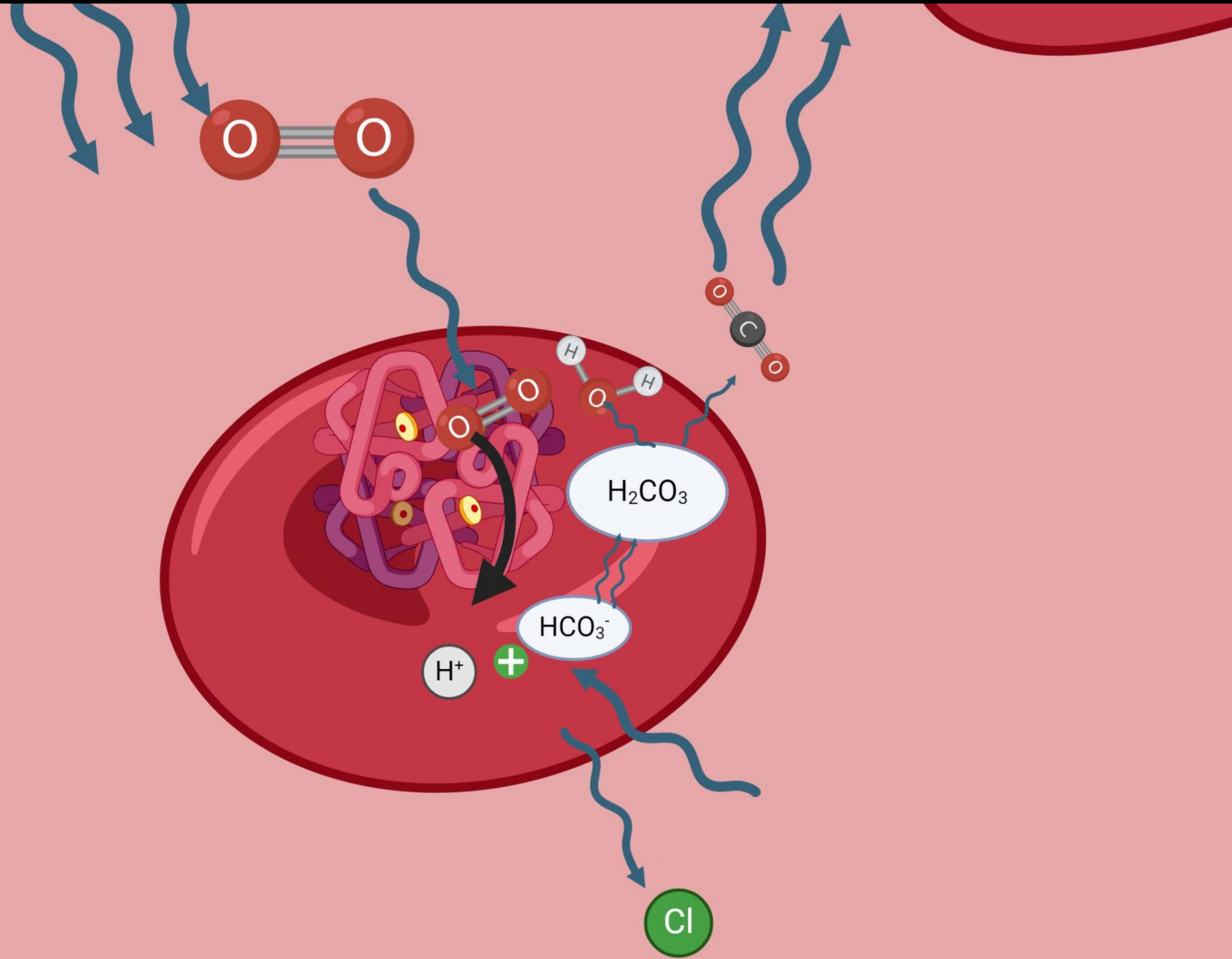
Biological Buffers



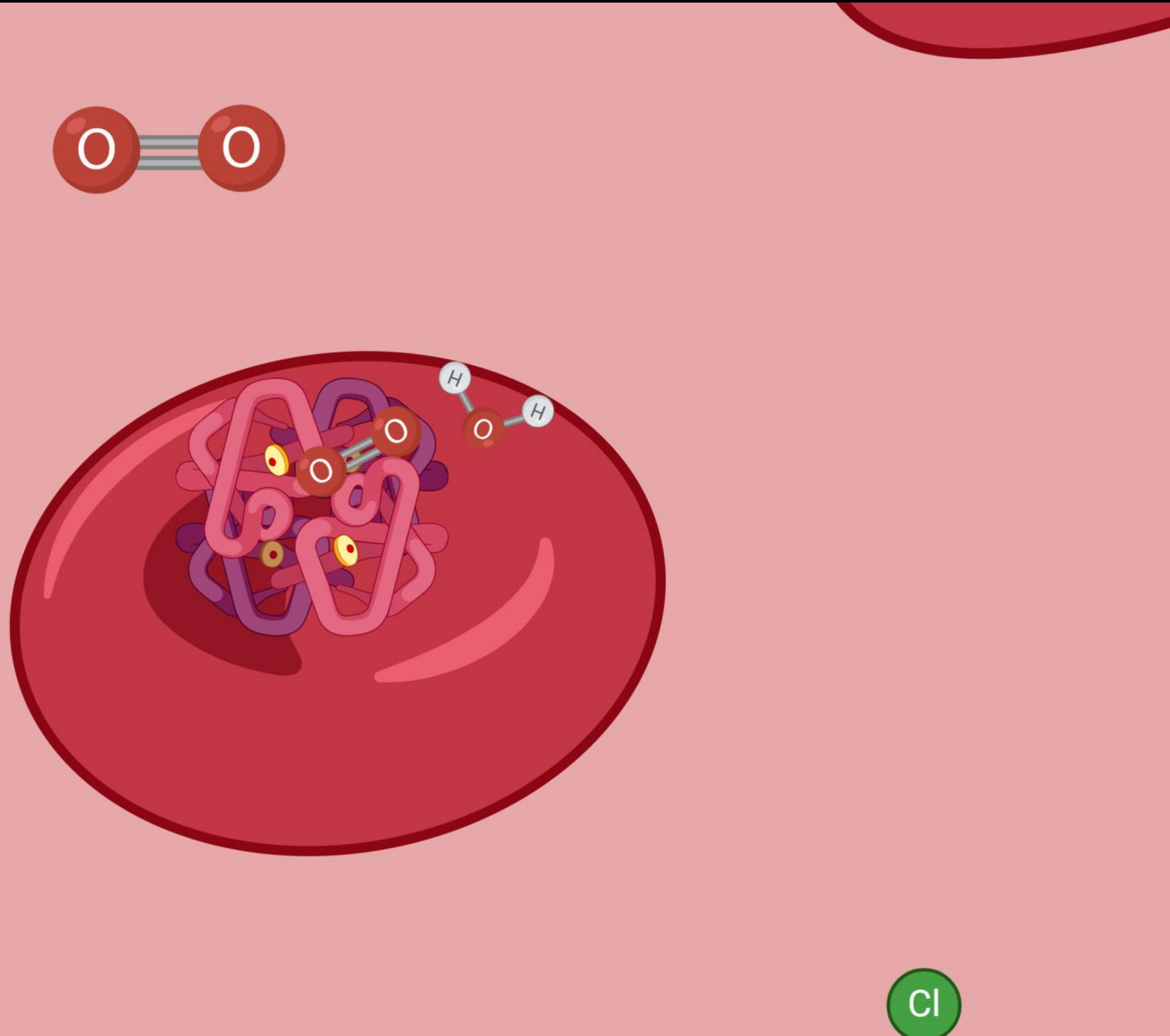
Biological Buffers



Biological Buffers

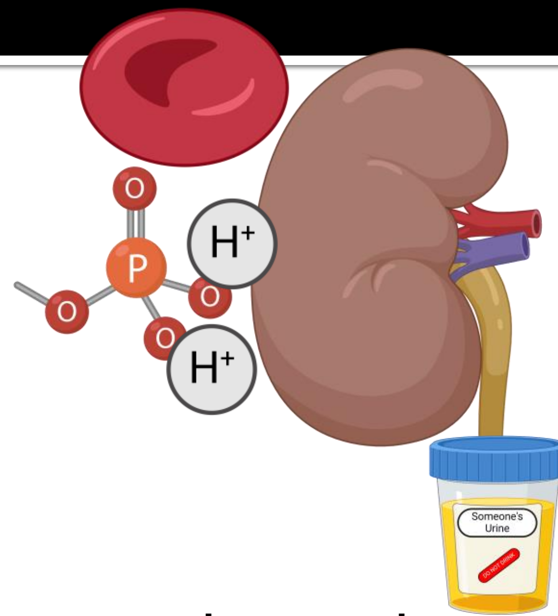


Biological Buffers

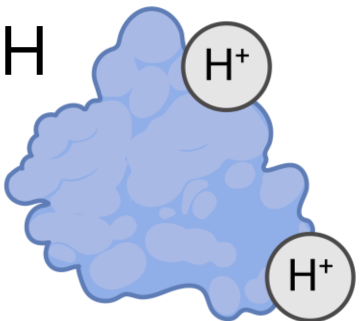


Biological Buffers

- Phosphate Buffer
  - HPO_4 & $H_2PO_4^-$



- Proteins
  - Can accept or donate H^+ depending on pH



- Hemoglobin
  - Oxyhemoglobin = stronger acid deoxy-weaker

NEXT LEVEL Buffers

- Henderson Hasselbalch Equation
- $pH = pK_a + \log([base]/[acid])$
  - pK_a dissociation constant
  - For the Bicarb/Carbonic Acid buffer
    - $pH = pK_a + \log([HCO_3^-]/[H_2CO_3])$
      - pK_a at body temp is 6.1
    - H_2CO_3 is more of a concept
    - $H_2CO_3 \propto (0.031 \times pCO_2)$

$$pH = 6.1 + \log \frac{[HCO3 -]}{0.031 \cdot pCO_2}$$

NEXT LEVEL Buffers

- Base Excess
  - Calculated parameter
    - Indication of increased (or decreased) buffering capacity against acid
    - Normal BE = 0
    - ↑BE = metabolic alkalosis
    - ↓BE = metabolic acidosis
  - WHY?
    - How much base or acid to give the patient to return pH to 7.40

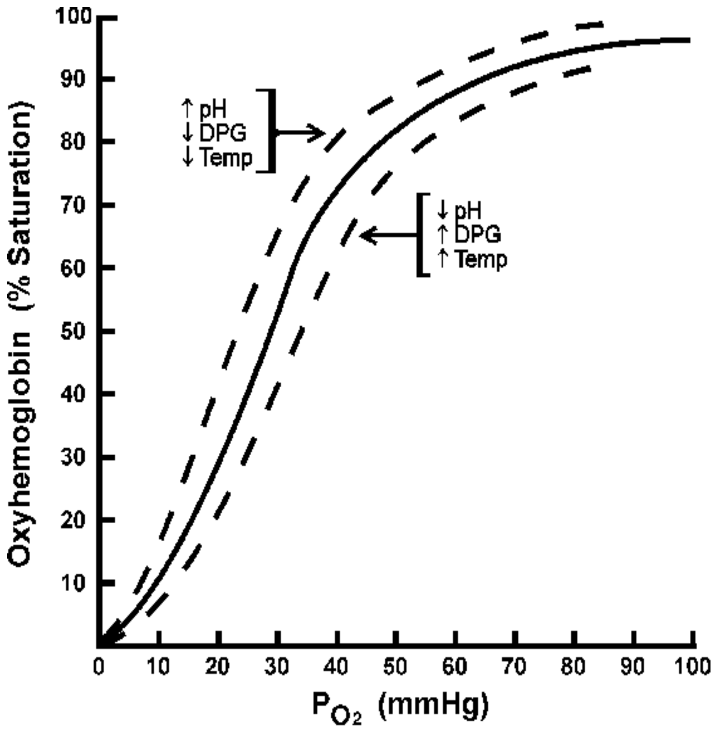
Blood Gas Parameters

Measured!

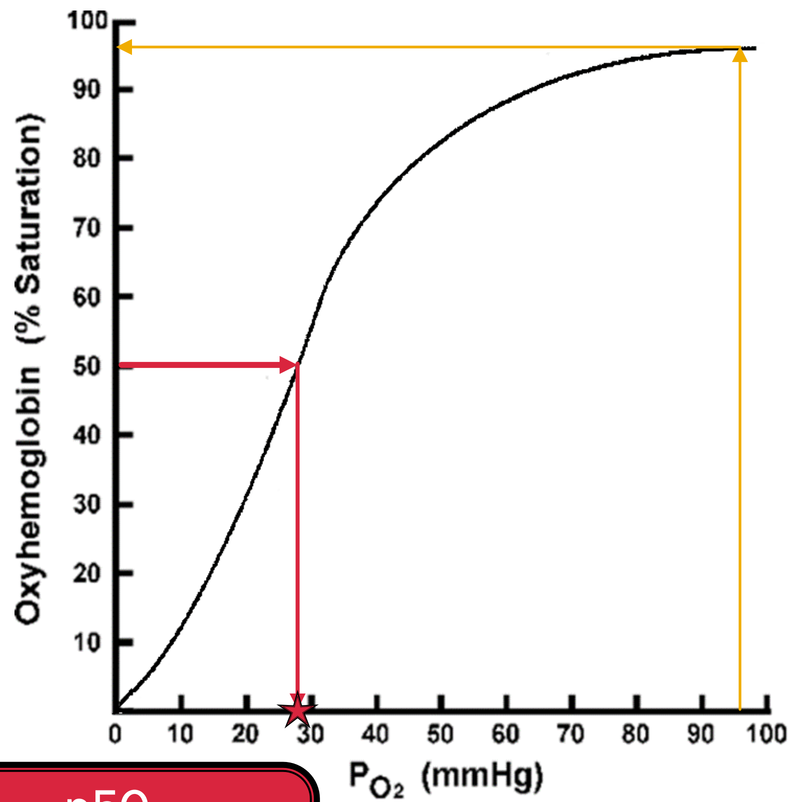
- pH 7.35-7.45
- pCO_2 (35-45 mmHg)
  - Inversely related to ventilation
  - Inversely related to pH
- pO_2 (80-110 mmHg)

Importance of pO_2

- pO_2
  - Ability of lungs to oxygenate blood
  - sO_2 is oxygen saturation
    - % of functional hemoglobin saturated with oxygen
    - 93-99% in arterial blood

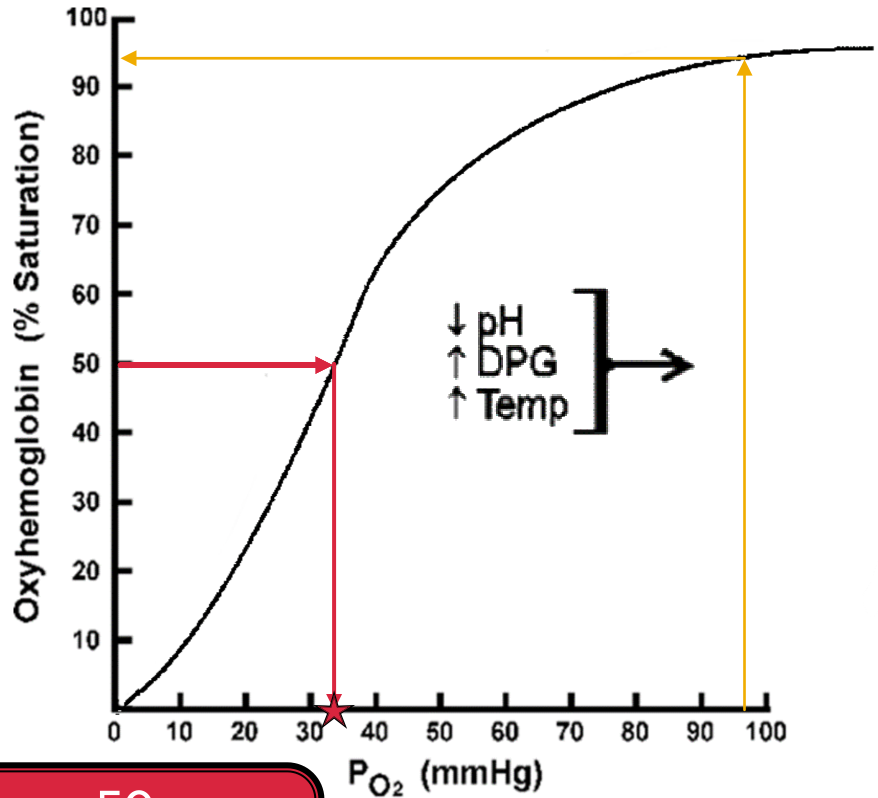


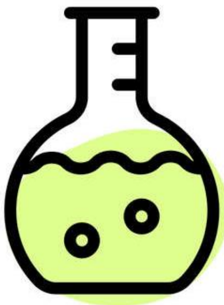
Importance of pO_2

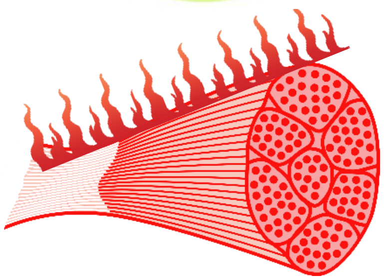


p50
Describes L<->R position

Importance of pO_2







p50
Describes L<->R
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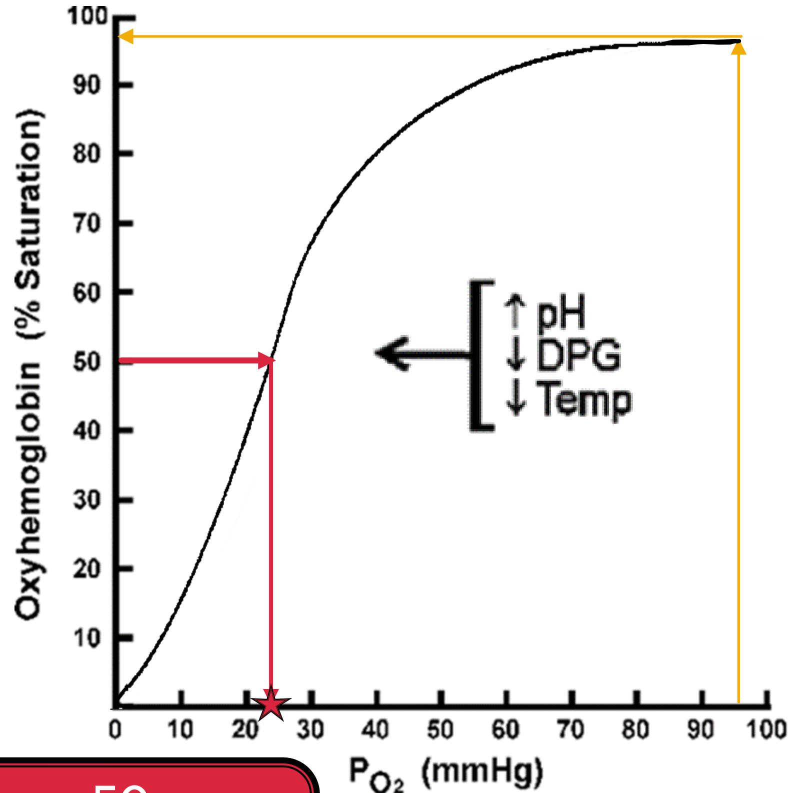
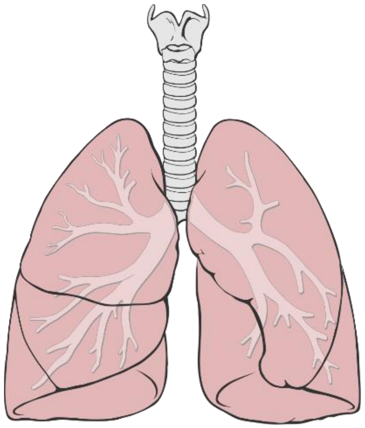
Importance of pO_2





p50
Describes L<->R position

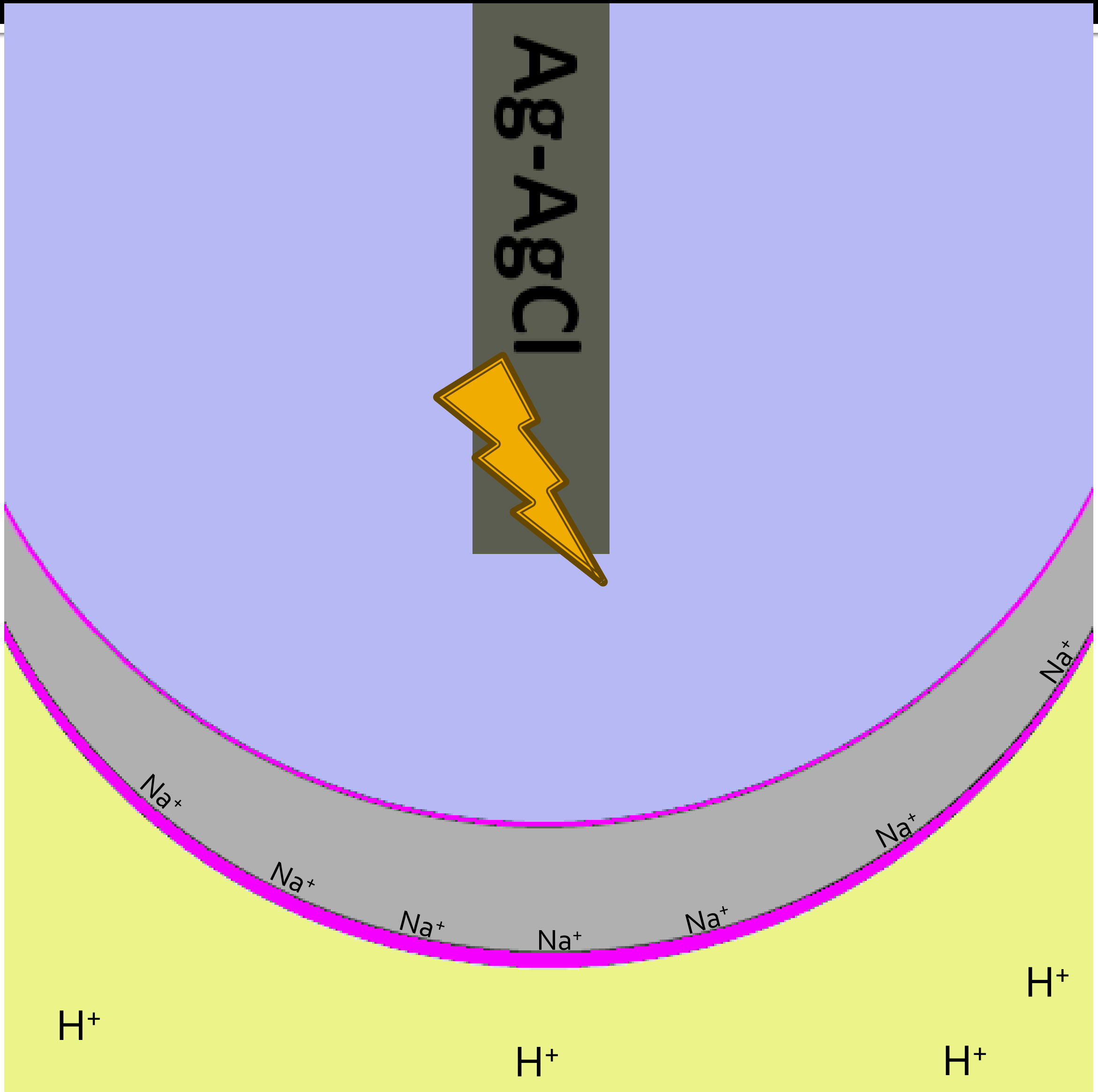
How do we do it? Analytical Mthds

- Blood gas analyzers use electrodes as sensing devices to measure pH, pO_2, pCO_2, Electrolytes, Glucose and Lactate.

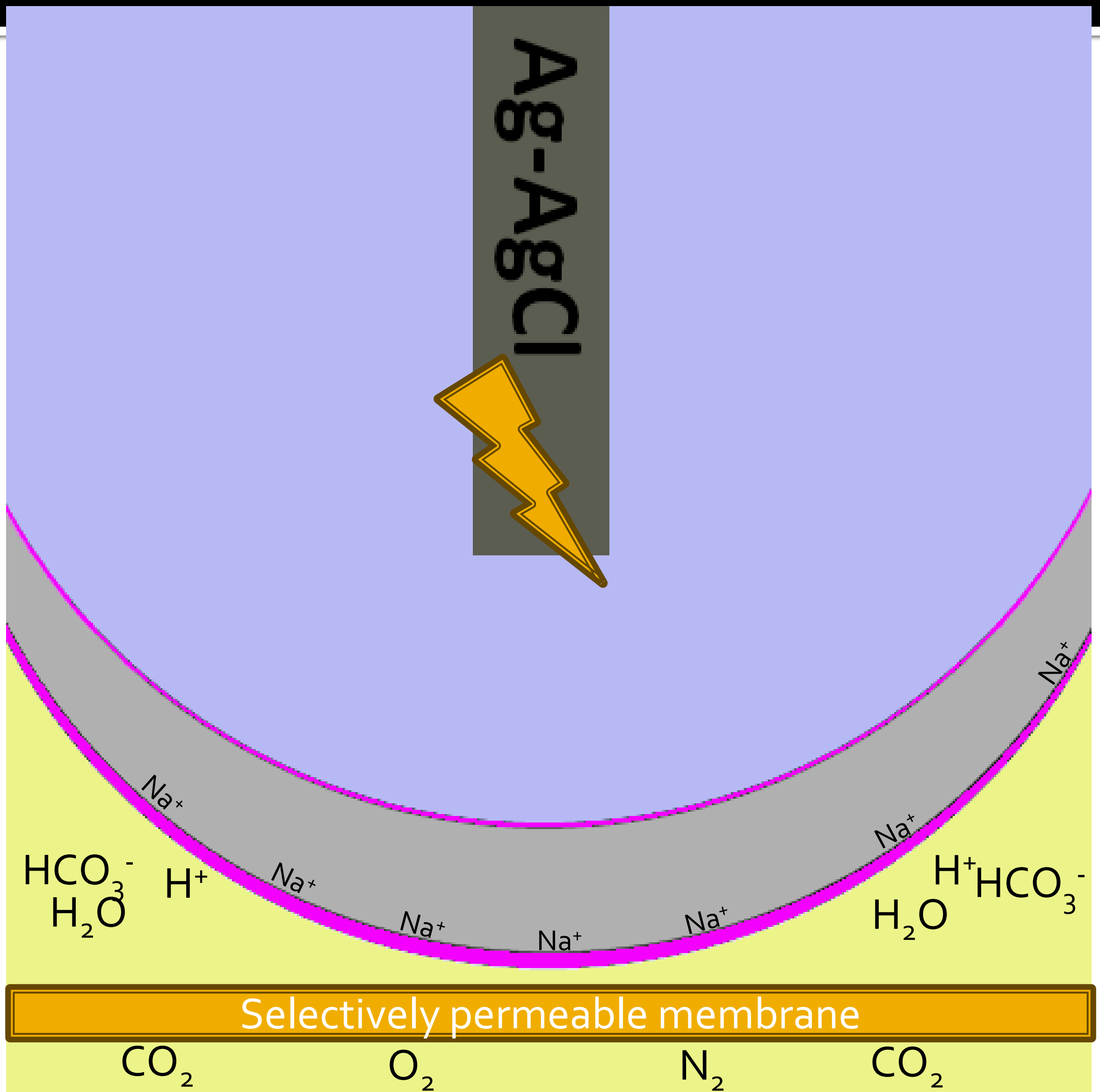
Potentiometric electrodes

- pH is determined using a glass membrane surrounding a Ag-AgCl electrode.
- pCO_2 is determined using a modified pH electrode, called a *Severinghaus* electrode.
- Electrolytes (Na^+, K^+, Ionized Ca^{++}) are determined using Ion Selective Electrodes

Sensitive Glass Membranes

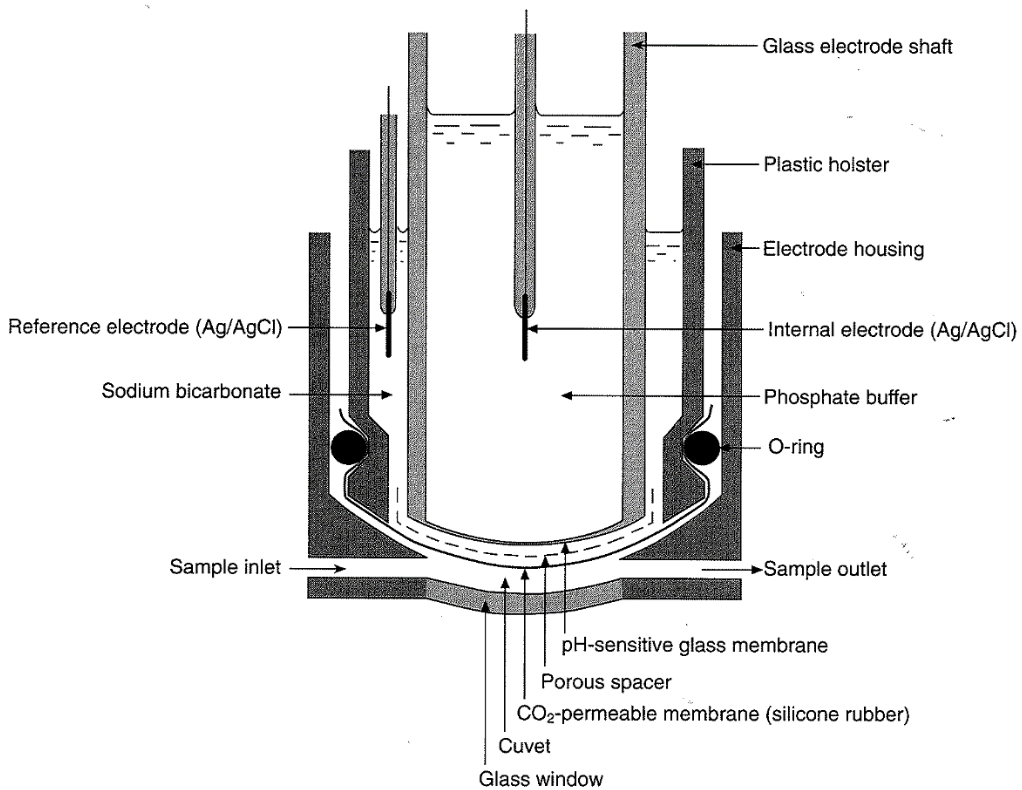


Sensitive Glass Membranes



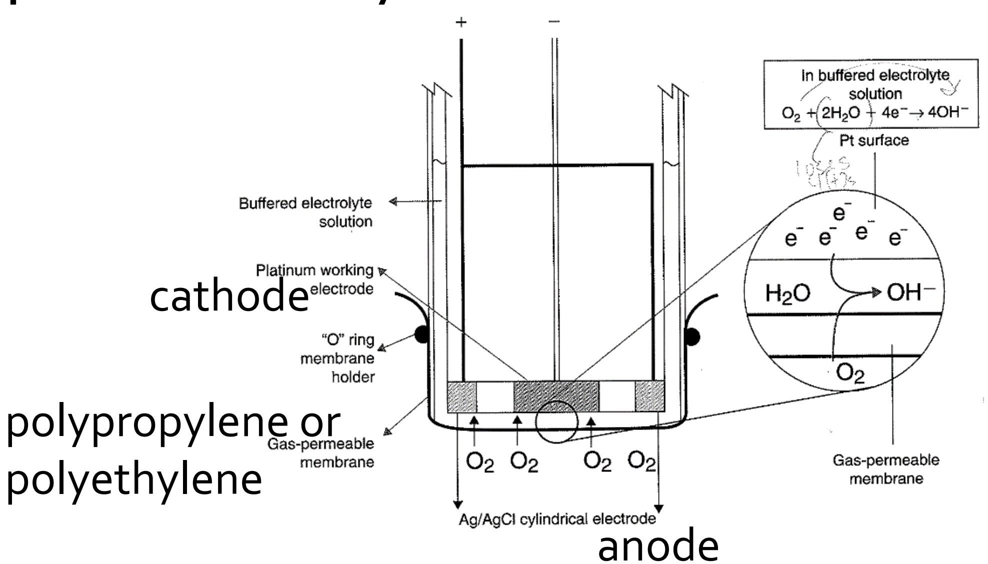
Potentiometric Electrodes

- Severinghaus electrode



Amperometric Electrodes

- Clark Electrode AMPEROMETRIC (we apply voltage)
  - O2 allows for flow of electrons from anode to cathode, as represented by current



Blood Gas Parameters

CALCULATED!!!

- Bicarbonate- Using H&H equation
- Base Excess- uses pCO_2, HCO_3^-, Hbg, pH O_2% sat to calculate
- %Sat- CAN be calculated from pO2 BE pH assuming normally shaped curves and that all Hgb can carry O2 (co-oximeter measures directly)

Calibration of Blood Gas results

- pH
  - 2 buffers that are NIST traceable are used for 1 & 2 pt calibrations
- PCO_2 and PO_2
  - Will measure the partial pressure of a gas "solution"
  - Gases have known CO_2 an O_2 concentrations
    - Gases behave differently, the O_2 electrode accounts for this with a correction factor since the gas diffuses across the membrane more quickly

Control of Blood Gas Analyzers

- Difficult to find ideal control
  - thick matrix (whole blood)
  - unstable analytes (dissolved gases)
- Commercial controls
  - Aqueous buffers that are sealed in vials
    - does not behave like patient specimen no protein or surface tension
    - contaminated by air quickly (single use)

Control of Blood Gas Analyzers

- Fluorocarbon-based controls
  - high oxygen carrying capacity
  - temperature sensitive
  - long shelf life
  - STILL not whole blood

Control of Blood Gas Analyzers

- Tonometer
  - whole blood is placed into container with antifoaming agent
  - gas bubbled into blood for 15-20 minutes
  - similar to specimens
  - cheap
  - PO_2 PCO_2 are controllable
  - YOU WOULD BE NUTS TO USE THIS

Assessing Blood Gas results

- First things first!
  - Always look at pH first
    - >7.45 alkalosis
    - <7.35 acidosis

  - Next we will want to know WHY they are the way the are…
    - is it a metabolic issue? kidney
    - is it a respiratory issue? lungs

Assessing Blood Gas results

- HCO_3^- the metabolic component
  - If the bicarb is out of normal range in the same direction as the pH, it is the cause and it is either metabolic acidosis or alkalosis

i.e. pH = 7.47	pH = 7.25
HCO_3^-= 30 mmol/L (22-26)	HCO_3^-= 17
metabolic alkalosis	metabolic acidosis

Assessing Blood Gas Results

- pCO_2 the respiratory component
  - If the pCO_2 is the opposite of the pH, then the condition is a respiratory acidosis/alkalosis

i.e. pH = 7.49 | pH = 7.25

pCO_2= 28 mmHg (35-45) pCO_2= 58 mmHg

respiratory alkalosis | respiratory acidosis

Assessing Blood Gas Results

	pH	pCO_2	HCO_3
Resp. Acidosis	↓	↑	norm
Resp. Alkalosis	↑	↓	norm
Met. Acidosis	↓	norm	↓
Met. Alkalosis	↑	norm	↑

Assessing Blood Gas Results

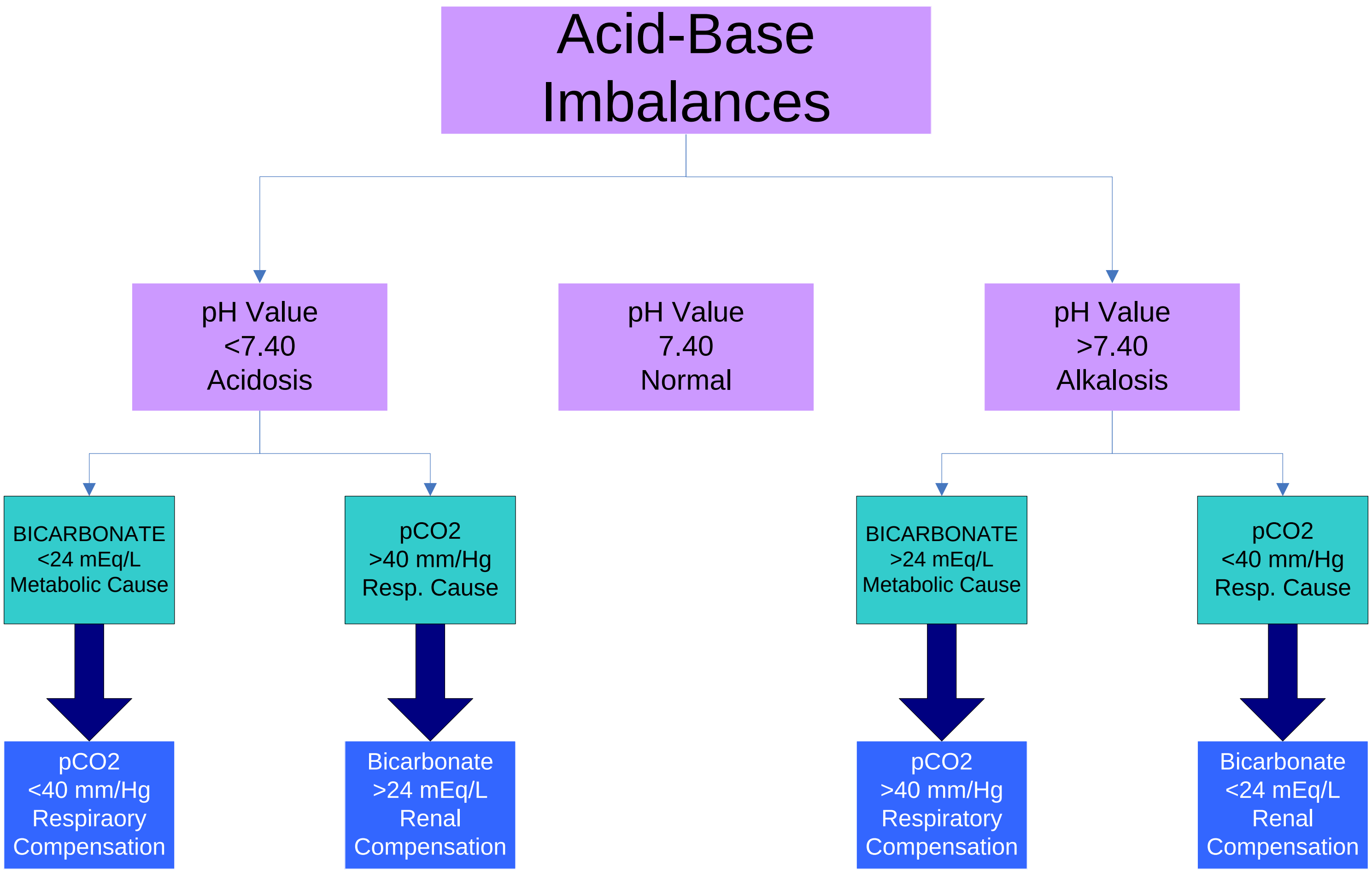
- If the body is out of acid base balance it tries to compensate
  - if the problem is respiratory (lungs) the kidneys will compensate-smoke, emphysema etc
  - if the problem is metabolic (kidneys) the lungs will compensate-DKA, kidney disease etc
- The cure is the opposite of the issue
  - solution for metabolic acidosis (low bicarb)?
    - respiratory alkalosis (low pCO_2 via hyperventilation)

Assessing Blood Gas Results

- If fully compensated the pH will return to the normal range
  - respiratory compensation is fast
  - metabolic compensation is slow

Case studies

- A 53 year old sustained major trauma in a motor vehicle accident. A blood gas was collected and the results follow:
  - pH: 7.53
  - HCO_3: 34 mmo/L
  - pCO_2: 42 mmHg


Acid-Base Imbalances
pH Value <7.40 Acidosis
pH Value 7.40 Normal
pH Value >7.40 Alkalosis
BICARBONATE <24 mEq/L Metabolic Cause
pCO2 >40 mm/Hg Resp. Cause
BICARBONATE >24 mEq/L Metabolic Cause
pCO2 <40 mm/Hg Resp. Cause
pCO2 <40 mm/Hg Respiraory Compensation
Bicarbonate >24 mEq/L Renal Compensation
pCO2 >40 mm/Hg Respiratory Compensation
Bicarbonate <24 mEq/L Renal Compensation

- Alkaline pH
- Increased HCO_3=Metabolic Cause
- Normal pCO_2=No Respiratory compensation

- Answer: Metabolic Alkalosis,
  Uncompensated

- **A 20 year old developed acute renal failure after aminoglycide therapy. An arterial blood gas revealed:**
  - **pH: 7.36**
  - **HCO_3: 16 mmol/L**
  - **pCO_2: 30 mmHg**

- Acidic pH
- Decreased HCO_3=Metabolic Cause
- Decreased pCO_2=Respiratory compensation
- Is the patient fully compensated?
- Answer: Metabolic Acidosis, Fully compensated

- A 60 year old man was admitted to a hospital with severe abdominal pain. The ABG showed:
  - pH: 7.65
  - pCO_2: 25 mmHg
  - HCO_3: 7 mmol/L

- Alkaline pH
- Decreased pCO_2=Respiratory cause
- Decreased HCO_3=Renal compensation
- Is the patient fully compensated?
- Answer: Respiratory Alkalosis, Partially compensated

- A hospitalized 72 year old with COPD and an upper respiratory infection showed an arterial blood gas:
  - pH: 7.30
  - pCO_2: 60 mmHg
  - HCO_3: 22 mmol/L

- Acidic pH
- Increased pCO_2=Respiratory Cause
- Normal HCO_3=Renal Status Quo
- Answer: Uncompensated Respiratory Acidosis

END

- Any questions?
  - Anyone?
    - Bueller?