

VIVEKANANDA COLLEGE

THAKURPUKUR

KOLKATA-700063

NAAC ACCREDITED 'A' GRADE



TOPIC: **REGULATION OF ACID BASE BALANCE**

COURSE TITLE: **ANIMAL PHYSIOLOGY: LIFE SUSTAINING SYSTEMS.**

PAPER: **CC9**

UNIT: **PRACTICAL**

SEMESTER: **6**

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NAME OF THE DEPARTMENT: **ZOOLOGY**

ACIDS & BASES

- A hydrogen ion is a single free proton released from a hydrogen atom.
- Molecules containing hydrogen atoms that can release hydrogen ions in solutions are, *acids*.
- Ions & molecules that can accept an H^+ , are bases.
- An alkali is a molecule formed by the combination of one or more alkaline metal (sodium, potassium, lithium etc.) with a highly basic ion like OH^- .
- Alkalosis is excess removal of H^+ from body fluids, & acidosis is excess addition of H^+ .
- Most acids & bases in ECF that are involved in normal acid-base regulation are weak acids & bases.

pH and H⁺ concentration of body fluids

	H ⁺ Concentration (mEq/L)	pH
Extracellular fluid		
Arterial blood	4.0×10^{-5}	7.40
Venous blood	4.5×10^{-5}	7.35
Interstitial fluid	4.5×10^{-5}	7.35
Intracellular fluid	1×10^{-3} to 4×10^{-5}	6.0-7.4
Urine	3×10^{-2} to 1×10^{-5}	4.5-8.0
Gastric HCl	160	0.8

SYSTEMS TO REGULATE H⁺ CONCENTRATION

- Chemical acid-base buffer systems of body fluids, which immediately combine with acid or base to prevent excessive changes in H⁺ concentration
- Respiratory center regulates removal of CO₂ (therefore H₂CO₃) from ECF
- Kidneys can excrete either acidic or alkaline urine, thereby readjusting ECF H⁺ concentration during acidosis & alkalosis

IMPORTANT BUFFER SYSTEMS OF THE BODY

- Bicarbonate buffer system
- Phosphate buffer system
- Proteins as intracellular buffers
- Phosphate buffer system
- Ammonia buffer system

RENAL CONTROL OF ACID-BASE BALANCE

- Kidneys control acid-base balance by excreting either acidic or basic urine.
- Large numbers of HCO_3^- filtered continuously into the tubules, & if they are excreted into urine, base is removed.
- Large numbers of H^+ are also secreted into tubular lumen, thus removing acid.

RENAL CONTROL OF ACID-BASE BALANCE

- Each day body produces about 80mEq nonvolatile acids, that are removed by renal excretion
- Kidneys must also prevent loss of bicarbonate
- Each day kidneys filter 4320mEq of bicarbonate, almost all is reabsorbed from tubules, thus conserving primary buffer system
- To reabsorb it as H_2CO_3 , 4320mEq H^+ must be secreted
- Additional 80mEq H^+ must be secreted to remove the nonvolatile acids

SECRETION OF H⁺ AND REABSORPTION OF HCO₃⁻ BY RENAL TUBULES

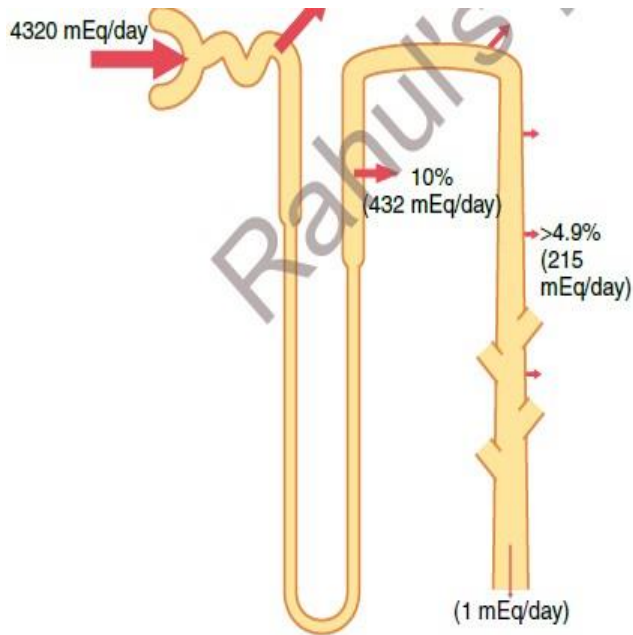


Figure 30-4 Reabsorption of bicarbonate in different segments of the renal tubule. The percentages of the filtered load of HCO₃⁻ absorbed by the various tubular segments are shown, as well as the number of milliequivalents reabsorbed per day under normal conditions.

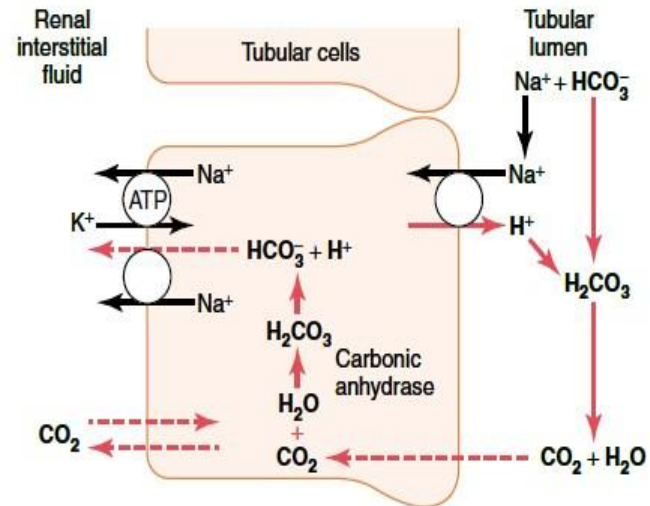


Figure 30-5 Cellular mechanisms for (1) active secretion of H⁺ into the renal tubule; (2) tubular reabsorption of HCO₃⁻ by combination with H⁺ to form carbonic acid, which dissociates to form carbon dioxide and water; and (3) sodium ion reabsorption in exchange for H⁺ secreted. This pattern of H⁺ secretion occurs in the proximal tubule, the thick ascending segment of the loop of Henle, and the early distal tubule.

PRIMARY ACTIVE SECRETION OF H⁺ IN THE INTERCALATED CELLS OF LATE DISTAL & COLLECTING TUBULES

- Late distal tubule onwards, the tubular epithelium secretes H⁺ by primary active transport.
- It occurs at the luminal membrane of tubular cell, where H⁺ is transported directly by a specific protein, a *hydrogen-transporting ATPase*.
- Primary active secretion occurs in *intercalated cells* of late distal tubule & collecting tubules.
- This mechanism is important in forming maximally acidic urine.
- H⁺ concentration can be increased as much as 900-fold in the collecting tubules.

PRIMARY ACTIVE SECRETION OF H⁺

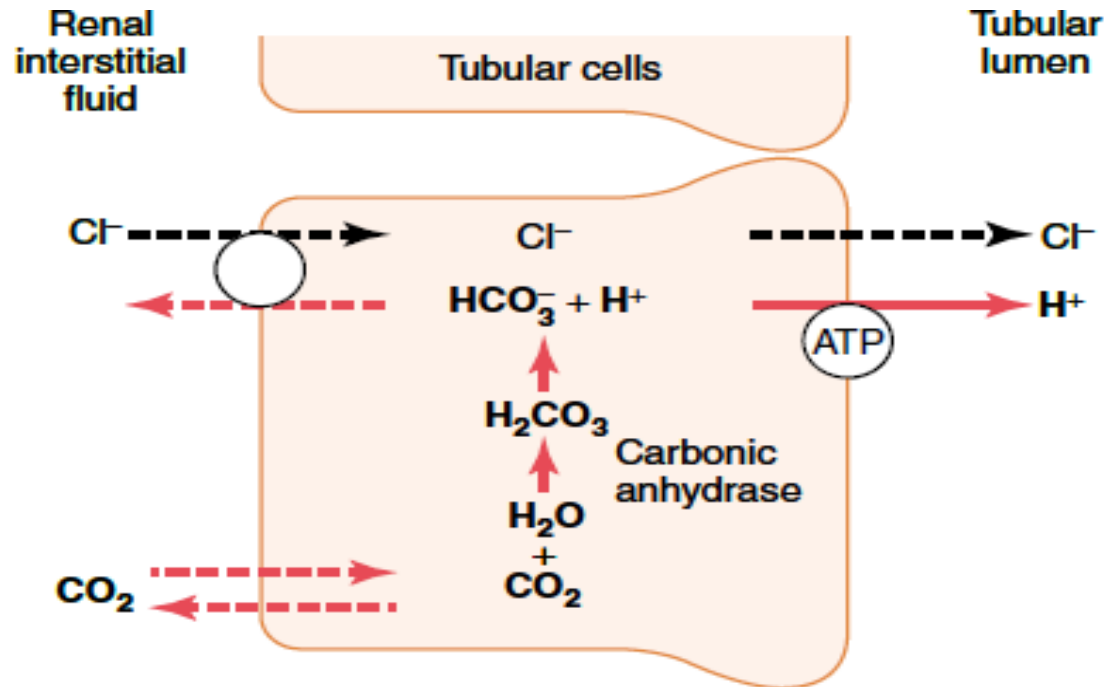


Figure 30-6 Primary active secretion of H⁺ through the luminal membrane of the intercalated epithelial cells of the late distal and collecting tubules. Note that one HCO₃⁻ is absorbed for each H⁺ secreted, and a chloride ion is passively secreted along with the H⁺.

COMBINATION OF EXCESS H⁺ WITH PHOSPHATE & AMMONIA BUFFERS IN THE TUBULE GENERATES “NEW” HCO₃⁻

- When H⁺ is secreted in excess of HCO₃⁻ filtered into the tubular fluid, only a small part of the excess H⁺ can be excreted in the ionic form because the minimal urine pH is about 4.5.
- Excess H⁺ is excreted by combining with phosphate & ammonia buffer.
- During acidosis, H⁺ combines with buffers other than HCO₃⁻, & this leads to generation of new HCO₃⁻ that can enter blood.

PHOSPHATE BUFFER SYSTEM CARRIES EXCESS H⁺ AND GENERATES “NEW” HCO₃⁻

- Phosphate buffer system composed of HPO₄⁻ & H₂PO₄⁻.
- Both become concentrated in urine as a result of water reabsorption.
- Phosphate is an important buffer in urine because slightly acidic pH is a very effective range for phosphate buffers.
- Once all HCO₃⁻ has been reabsorbed, excess H⁺ can combine with HPO₄⁻ to form H₂PO₄⁻ & can be excreted as NaH₂PO₄, carrying with it the excess H⁺.
- In this case, the HCO₃⁻ that is generated in the tubular cell & enters the peritubular blood represents a net gain of HCO₃⁻ by the blood, rather than a replacement of filtered HCO₃⁻.

H⁺ REMOVAL BY PHOSPHATE BUFFER

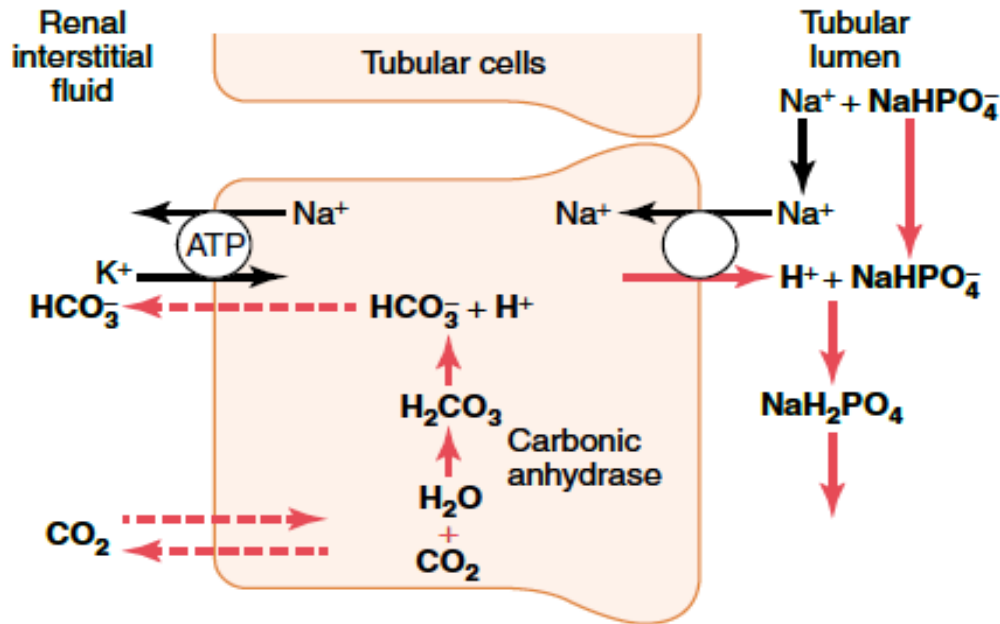


Figure 30-7 Buffering of secreted H⁺ by filtered phosphate (NaHPO_4^-). Note that a new HCO_3^- is returned to the blood for each NaHPO_4^- that reacts with a secreted H⁺.

EXCRETION OF H⁺ BY THE AMMONIA BUFFER SYSTEM

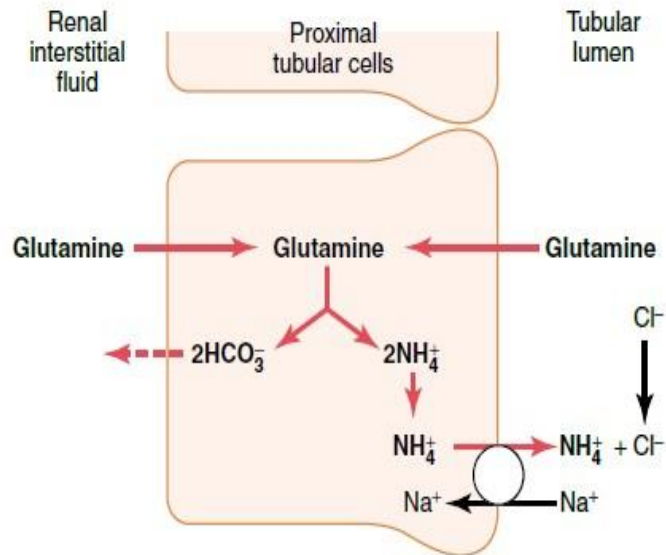


Figure 30-8 Production and secretion of ammonium ion (NH_4^+) by proximal tubular cells. Glutamine is metabolized in the cell, yielding NH_4^+ and bicarbonate. The NH_4^+ is secreted into the lumen by a sodium- NH_4^+ exchanger. For each glutamine molecule metabolized, two NH_4^+ are produced and secreted and two HCO_3^- are returned to the blood.

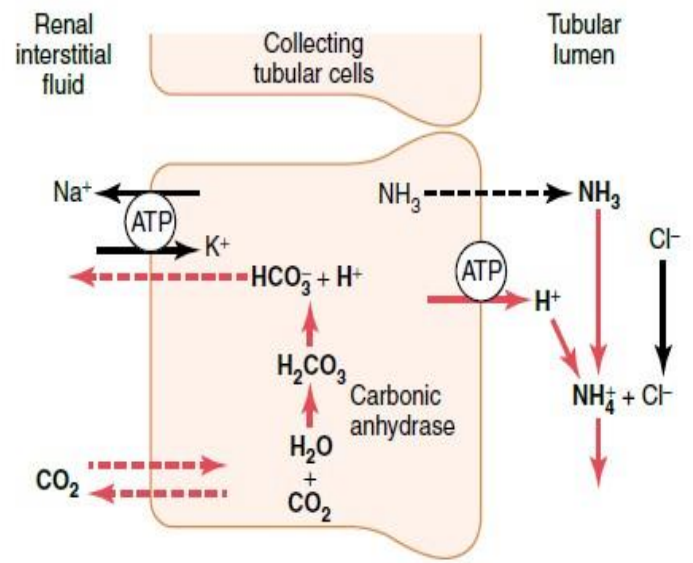


Figure 30-9 Buffering of hydrogen ion secretion by ammonia (NH_3) in the collecting tubules. Ammonia diffuses into the tubular lumen, where it reacts with secreted H^+ to form NH_4^+ , which is then excreted. For each NH_4^+ excreted, a new HCO_3^- is formed in the tubular cells and returned to the blood.

CHRONIC ACIDOSIS INCREASES NH_4^+ SECRETION

- Renal ammonium-ammonia system is subject to physiologic control.
- Increase in H^+ concentration stimulates renal glutamine metabolism, decrease in H^+ concentration has the opposite effect.
- In chronic acidosis, acid is eliminated & HCO_3^- is produced mainly by the ammonia buffer system.

QUANTIFYING RENAL ACID-BASE EXCRETION

- Bicarbonate excretion is calculated as urine flow rate multiplied by urinary HCO_3^- concentration. This number indicates how rapidly the kidneys are removing HCO_3^- from the blood (which is the same as adding an H^+ to the blood).
- The amount of new HCO_3^- contributed to the blood at any given time is equal to the amount of H^+ secreted that ends up in the tubular lumen with nonbicarbonate urinary buffers (ammonium & phosphate).
- Amount of HCO_3^- added to the blood is calculated by NH_4^+ excretion (urine flow rate x urinary NH_4^+ conc.)
- Rest of the non-bicarbonate, non- NH_4^+ buffer excreted in the urine is measured by determining a value known as titratable acid (the amount measured by titrating urine with a strong base, such as NaOH to a pH of 7.4).

The number of milliequivalents of NaOH required to return the urinary pH to 7.4 equals the number of milliequivalents of H⁺ added to the tubular fluid that combined with phosphate & other organic buffers.

Thus, the net acid excretion by the kidneys can be assessed as
Net acid excretion = NH_4^+ excretion + urinary titratable acid - HCO_3^- excretion

In acidosis, the net acid excretion increases markedly, especially because of increased NH_4^+ secretion, thereby removing acid from blood. Therefore, there is a net addition of HCO_3^- back to the blood as more NH_4^+ & urinary titratable acid are excreted.

In alkalosis, titratable acid & NH_4^+ secretion drop to 0, whereas HCO_3^- excretion increases. Therefore, in alkalosis, there is a negative net acid secretion.

Reference: Guyton & Hall, Textbook of Medical Physiology,
Twelfth Edition

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