- Kidneys eliminate non-volatile acids (H_2SO_4, H_3PO_4) (~ 80 mmol/day)
- Filtration of HCO_3^- (~ 4320 mmol/day)
- Secretion of H^+ (~ 4400 mmol/day)
- Reabsorption of HCO_3^- (~ 4319 mmol/day)
- Production of new HCO_3^- (~ 80 mmol/day)
- Excretion of HCO_3^- (1 mmol/day)

Kidneys conserve HCO_3^- and excrete acidic or basic urine depending on body needs

$$pH = pK + \log \frac{HCO_3^-}{\alpha \; pCO_2}$$

- Increased pCO_2 increases H^+ secretion

  i.e. respiratory acidosis

- Increased extracellular H^+ increases H^+ secretion

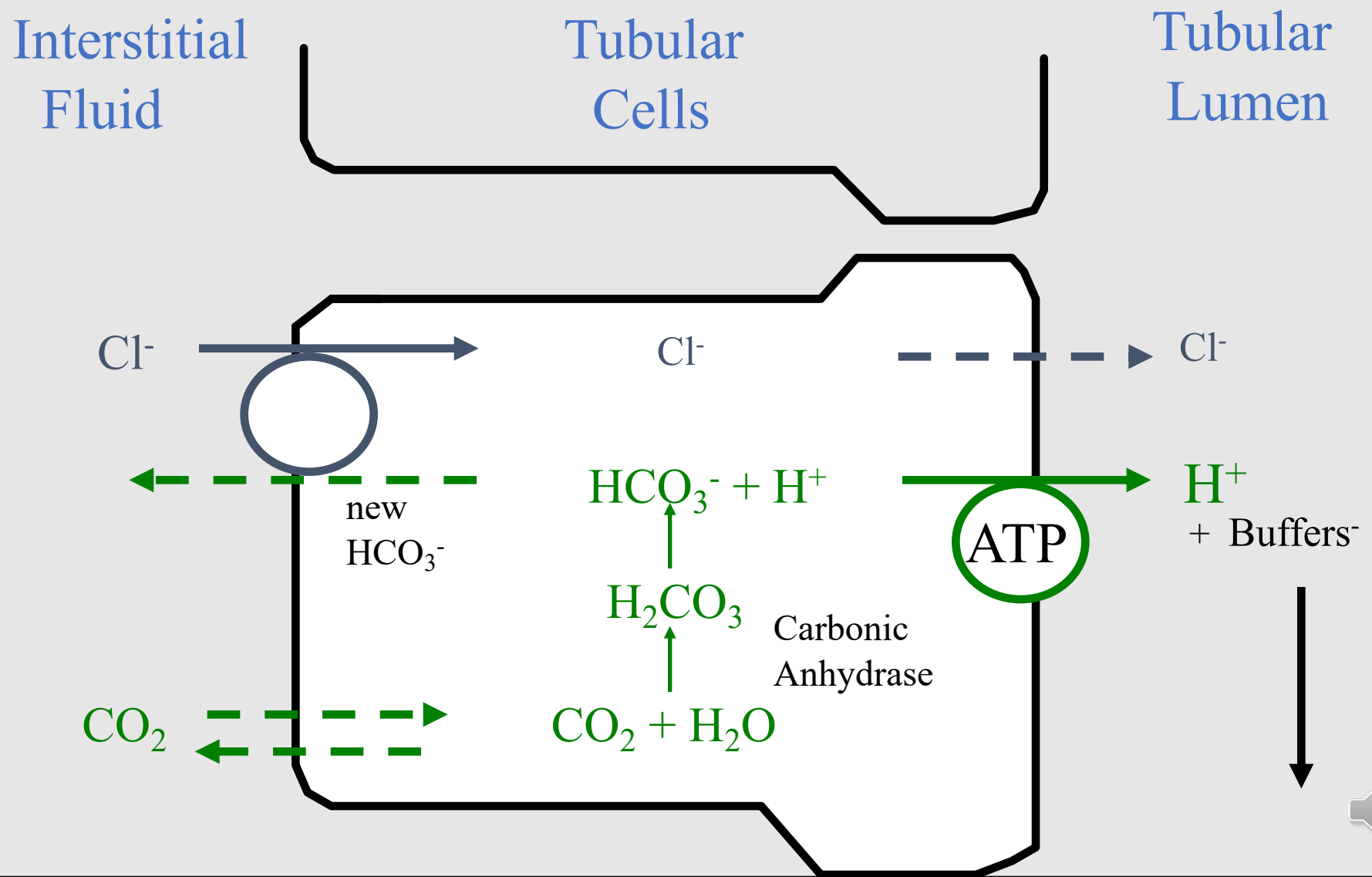
  i.e. metabolic or respiratory acidosis

- Increased tubular fluid buffers increases H^+ secretion

  i.e. metabolic or respiratory acidosis

- Acidosis:
  - increased H^+ secretion
  - increased HCO_3^- reabsorption
  - production of new HCO_3^-
- Alkalosis:
  - decreased H^+ secretion
  - decreased HCO_3^- reabsorption
  - loss of HCO_3^- in urine

In acidosis all HCO_3^- is titrated and excess H^+ in tubule is buffered



Minimum urine pH = 4.5

$= 10^{-4.5}$

$= 3 \times 10^{-5}$ moles/L

i.e. the maximal $[H^+]$ of urine is 0.03 mmol/L

Yet, the kidneys must excrete, under normal conditions, at least 60 mmol non-volatile acids each day. To excrete this as free H^+ would require :

$$\frac{60 \text{ mmol}}{.03 \text{mmol/L}} = 2000 \text{ L per day !!!}$$

Buffering of secreted H^+ by filtered phosphate ($NaHPO_4^-$) and generation of "new" HCO_3^-

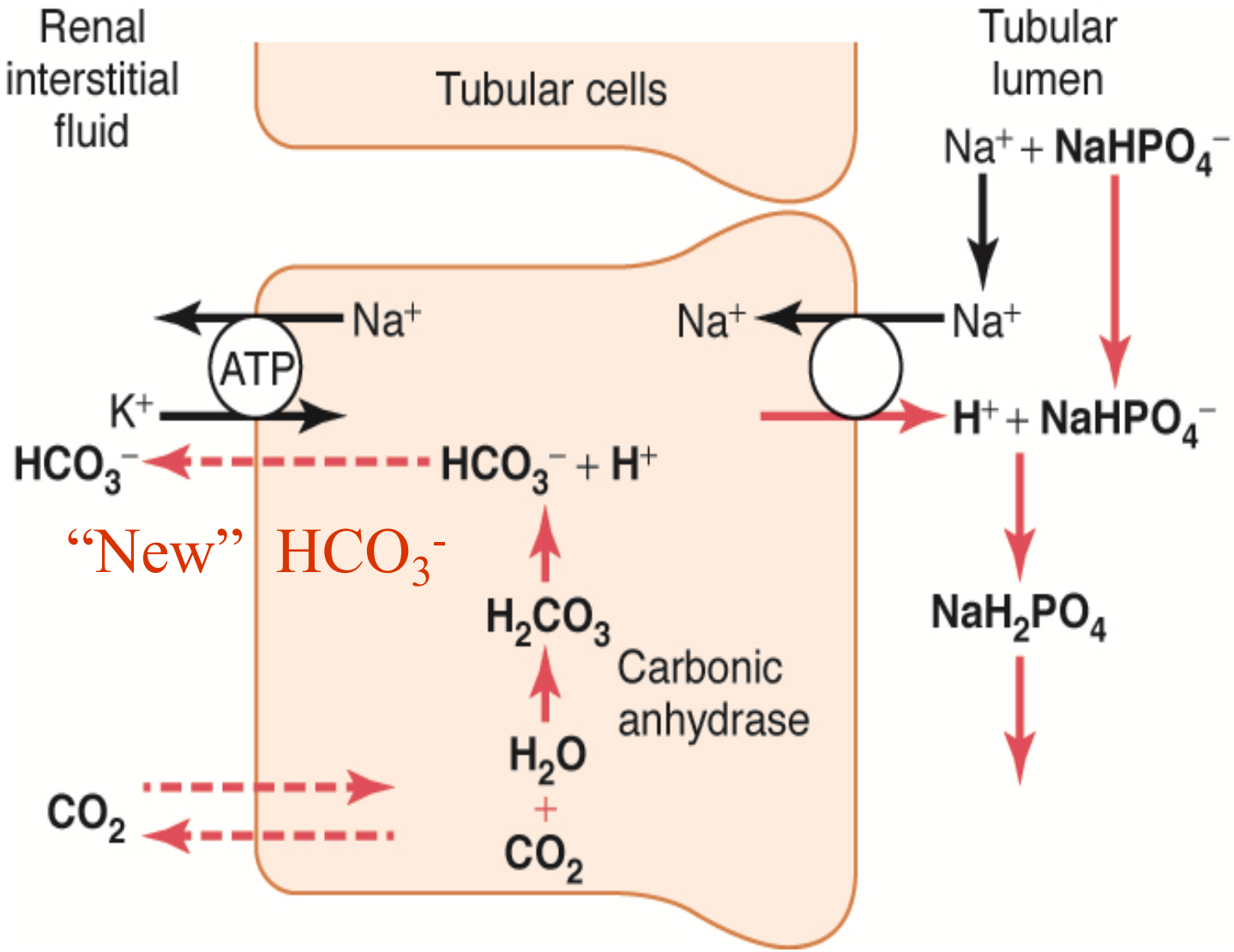
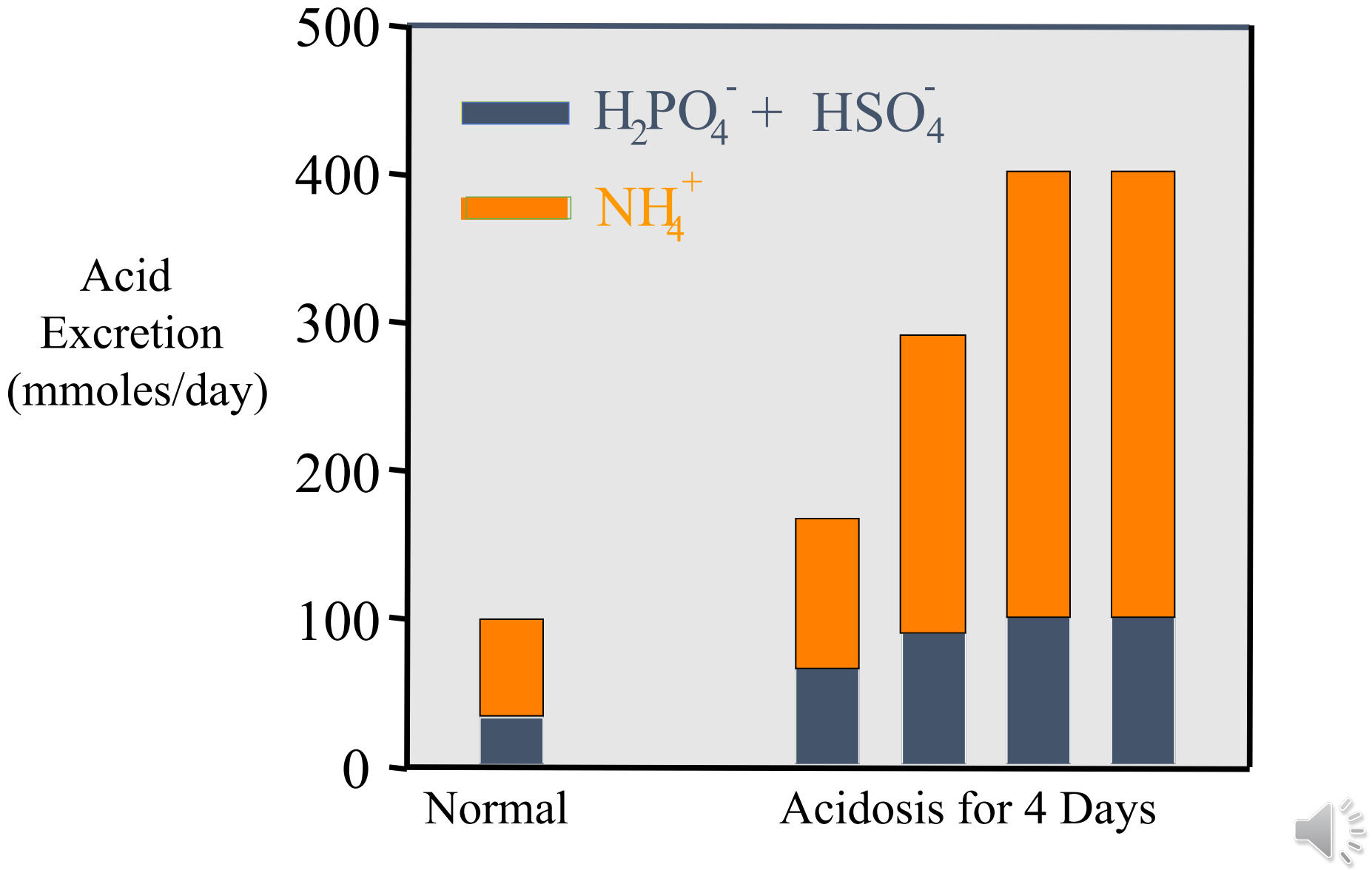


Figure 30-7.

There is a high concentration of phosphate in the tubular fluid; pK = 6.8

Phosphate normally buffers about 30 mmol/day H^+ (about 100 mmol/day phosphate is filtered but 70 % is reabsorbed)

Phosphate buffering capacity does not change much with acid-base disturbances (phosphate is not the major tubular buffer in chronic acidosis


Acid Excretion (mmoles/day)
500
400
300
200
100
0
$H_2PO_4^-$ + HSO_4^-
NH_4^+
Normal
Acidosis for 4 Days

Production and secretion of NH_4^+ and HCO_3^- by proximal, thick loop of Henle, and distal tubules

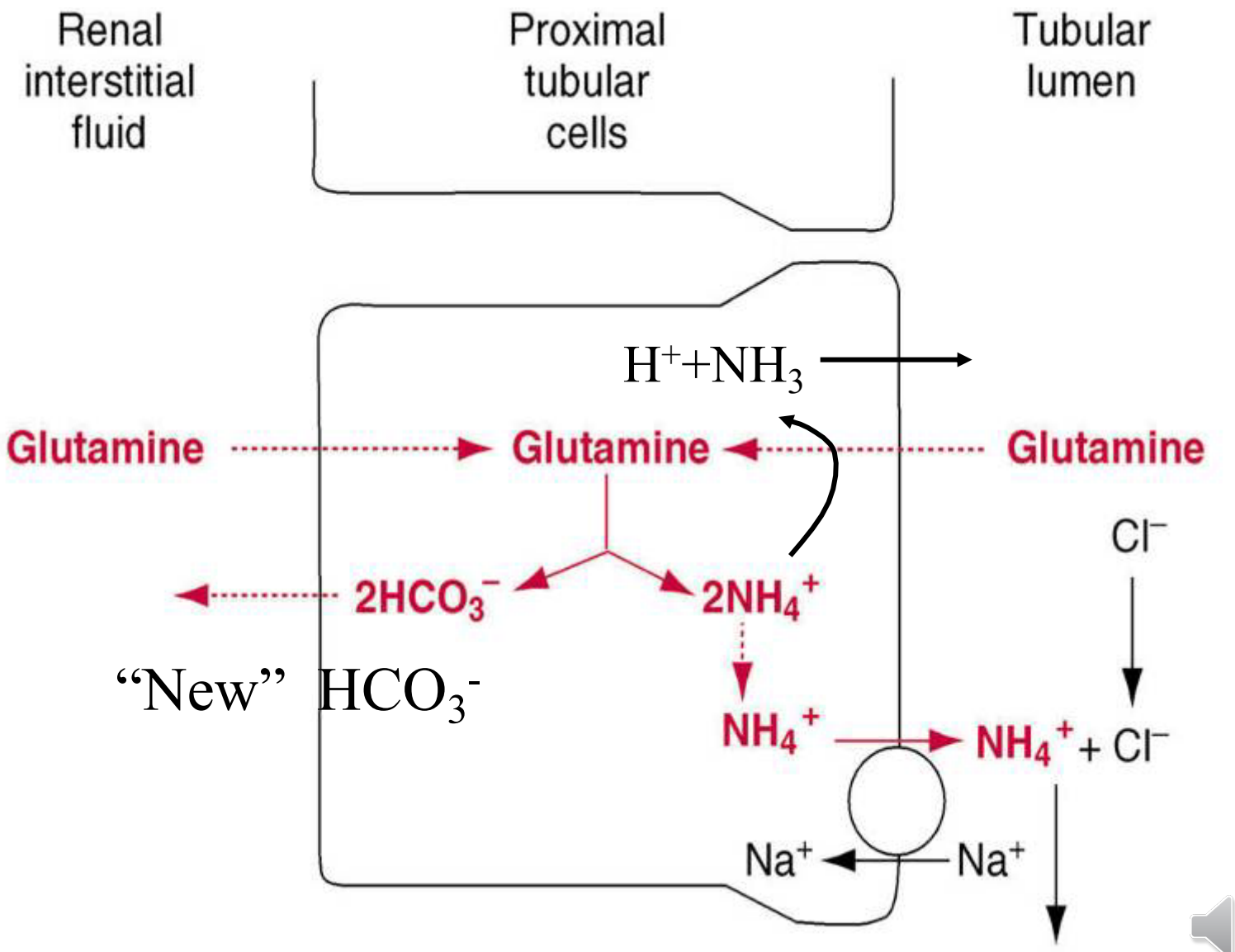


Figure 30-8.

Buffering of hydrogen ion secretion by ammonia (NH_3) in the collecting tubules.

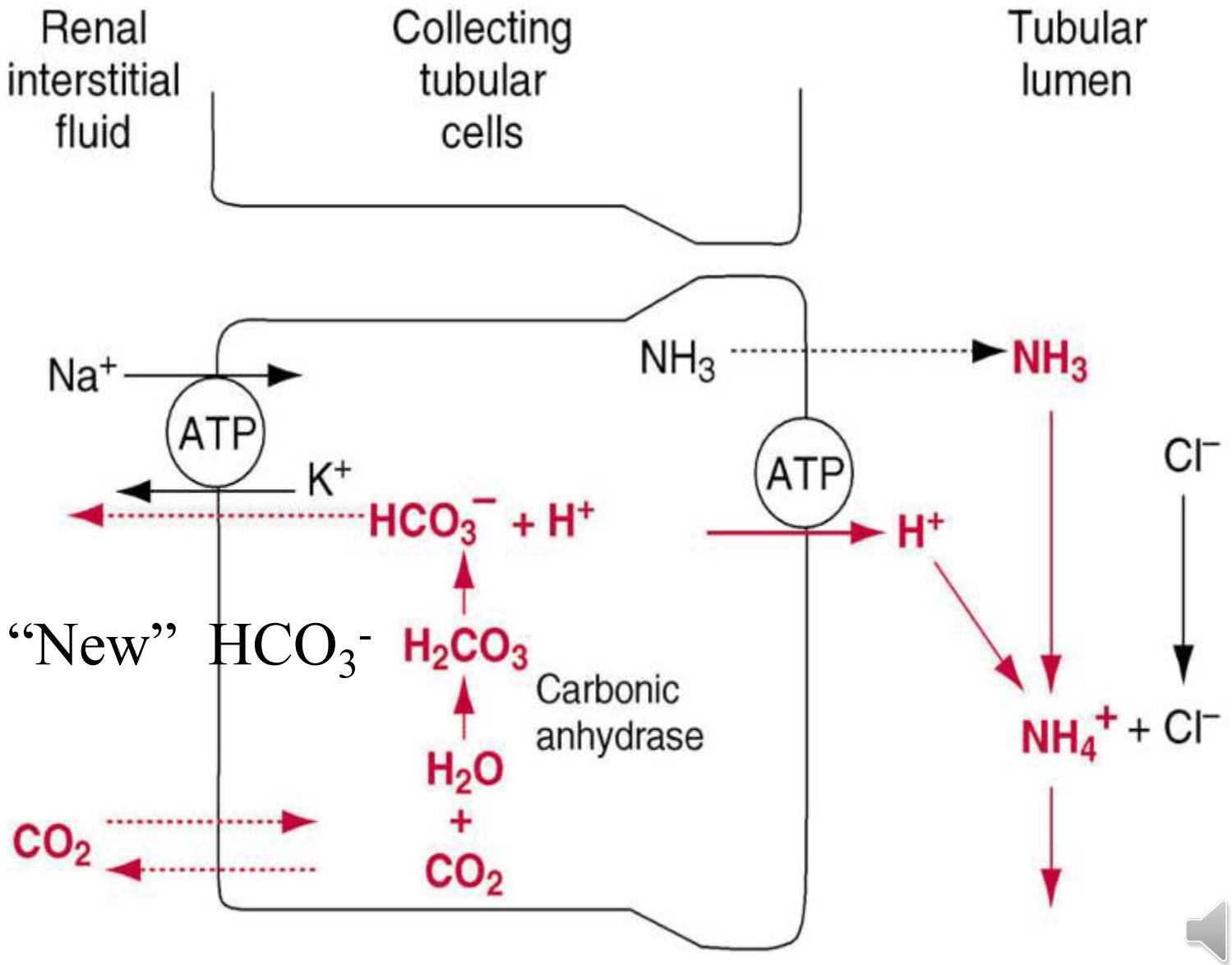


Figure 30-9.

Total H^+ secretion

= 4320 mEq of H+ secreted (HCO3)+ 60 mEq of H+ non-volatile= 4380

Total H^+ secretion = 4380 mmol/day

= HCO_3^- reabsorption (4320 mmol/d)

+ titratable acid ($NaHPO_4^-$) (30 mmol/d)

+ NH_4^+ excretion (30 mmol/d)

Net H+ excretion=

H+ excreted by buffers not bicarbonate(=new bicarb) - newH+ added to blood(=HCO3- excreted)

Net H^+ excretion = 59 mmol/day

= titratable acid (30 mmol/d)

+ NH_4^+ excretion (30 mmol/d)

- HCO_3^- excretion (1 mmol/d)(or HCO3- exc)

Net addition of HCO_3^- to body (i.e. net loss of H^+)

Titratable acid	= 30 mmol/day
+ NH_4^+ excretion	= 30 mmol/day
- HCO_3^- excretion	= 1 mmol/day
Total	= 59 mmol/day

Increased addition of HCO_3^- to body by kidneys
(increased H^+ loss by kidneys)

Titratable acid	= 35 mmol/day (small increase)
NH_4^+ excretion	= 165 mmol/day (increased)
HCO_3^- excretion	= 0 mmol/day (decreased)
Total	= 200 mmol/day

This can increase to as high as 500 mmol/day

Net loss of HCO_3^- from body
(i.e. decreased H^+ loss by kidneys)

Titratable acid	= 0 mmol/day (decreased)
NH_4^+ excretion	= 0 mmol/day (decreased)
HCO_3^- excretion	= 80 mmol/day (increased)
Total	= 80 mmol/day

HCO_3^- excretion can increase markedly in alkalosis

$$H_2O + CO_2 \longleftrightarrow H_2CO_3 \longleftrightarrow H^+ + HCO_3^-$$

$$pH = pK + \log \frac{HCO_3^-}{\alpha \; pCO_2}$$

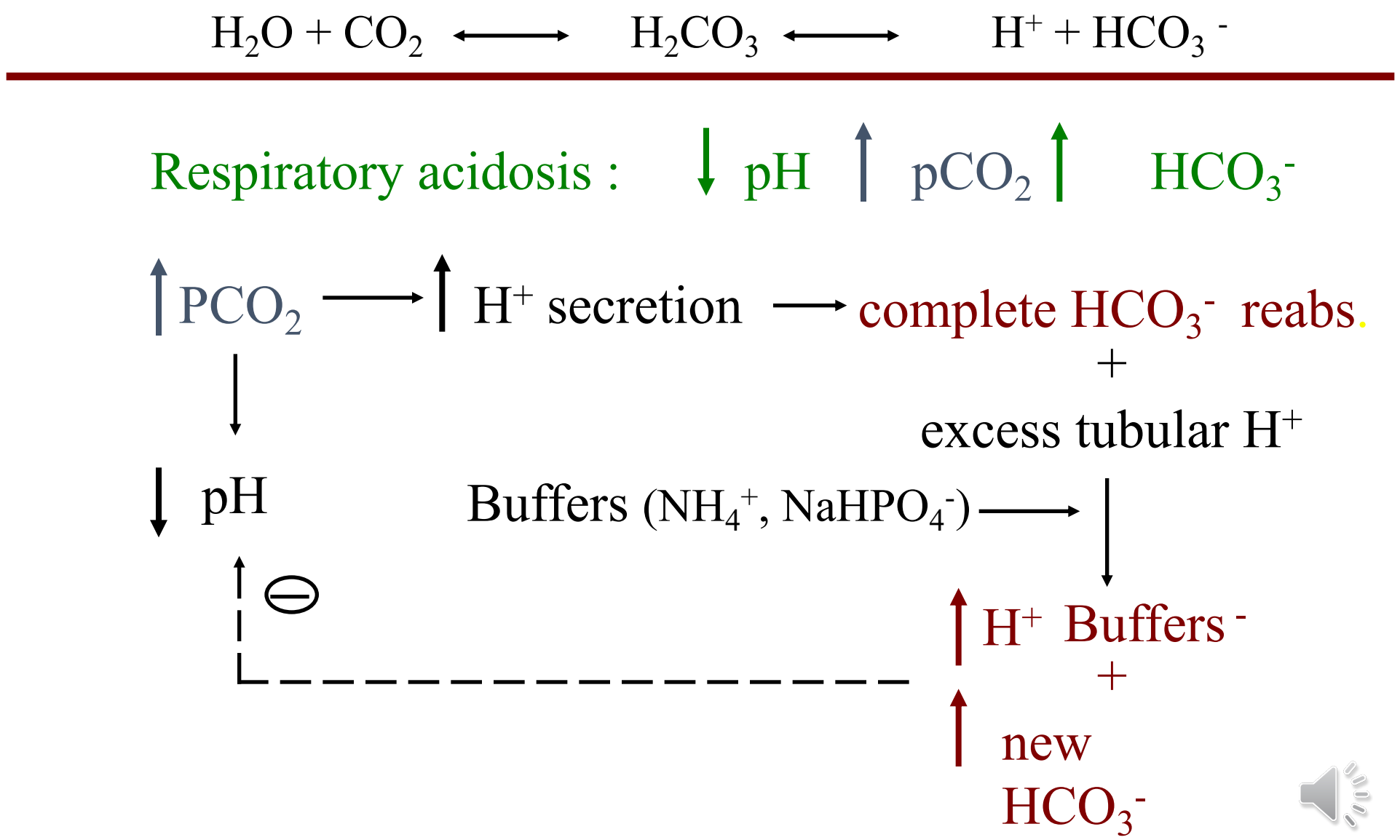
Acidosis : pH < 7.4

- metabolic : ↓ HCO_3^-
- respiratory : ↑ pCO_2

Alkalosis : pH > 7.4

- metabolic : ↑ HCO_3^-
- respiratory : ↓ pCO_2

- Acidosis:
  - increased H^+ excretion
  - increased HCO_3^- reabsorption
  - production of new HCO_3^-
- Alkalosis:
  - decreased H^+ excretion
  - decreased HCO_3^- reabsorption
  - loss of HCO_3^- in urine


$H_2O + CO_2 \longleftrightarrow H_2CO_3 \longleftrightarrow H^+ + HCO_3^-$
Respiratory acidosis : ↓ pH ↑ pCO_2 ↑ HCO_3^-
↑ PCO_2 → ↑ H^+ secretion → complete HCO_3^- reabs.
+
excess tubular H^+
↓ pH
Buffers (NH_4^+, $NaHPO_4^-$) →
⊖
↑ H^+ Buffers $^-$
+
new
HCO_3^-

Metabolic acidosis : ↓ pH ↓ pCO_2 ↓ HCO_3^-

↓ HCO_3^- → ↓ HCO_3^- filtration → complete HCO_3^- reabs.
+
excess tubular H^+

↓ pH

Buffers (NH_4^+, $NaHPO_4$-) →

⊖

↑ H^+ Buffers $^-$
+
↑ new HCO_3^-

Respiratory alkalosis : ↑ pH ↓ pCO_2 ↓ HCO_3^-