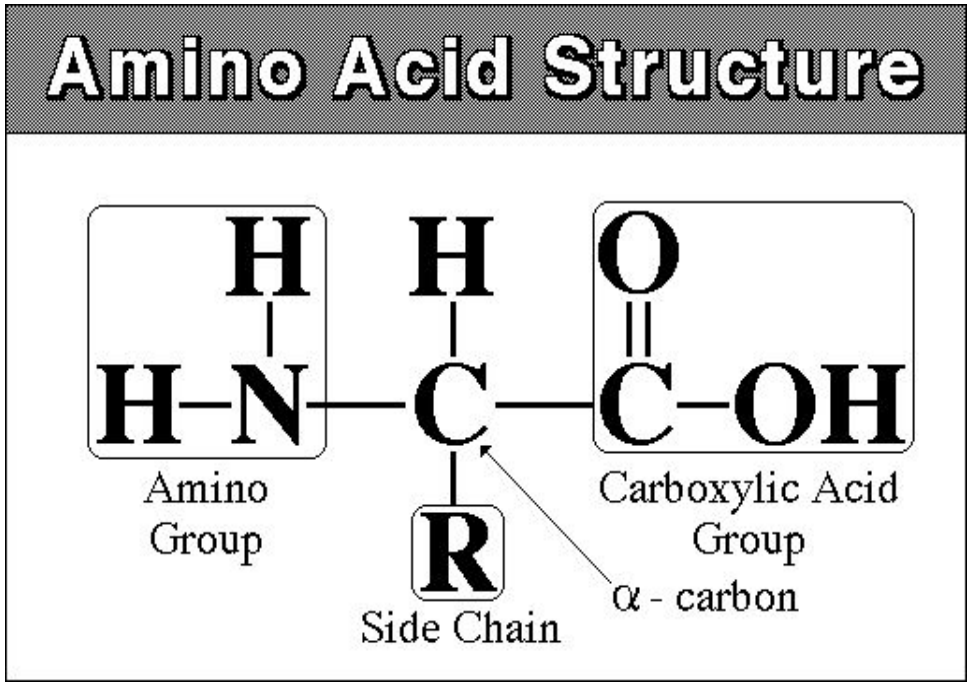

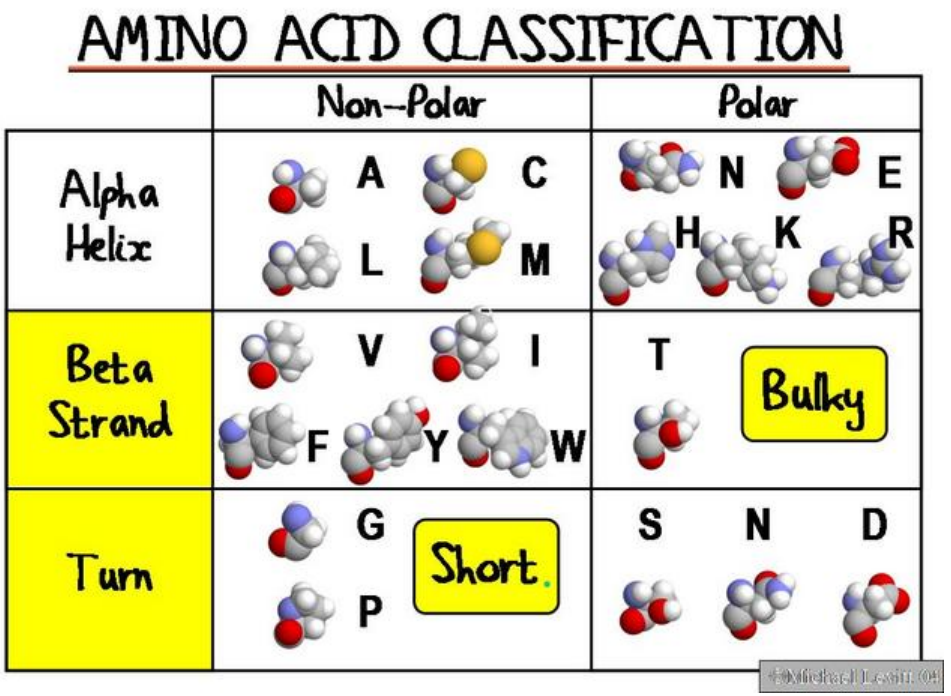

營養生化學(0070210)

Nutritional biochemistry

保健營養學系三年級

授課教師：保健營養學系趙振瑞(Jane Chao)教授

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Amino Acid Metabolism

Learning Objectives

- **Amino acid classification (0.5 h)**
- **Amino acid digestion and absorption (0.5 h)**
- **Amino acid metabolism (1.5 h)**
- **Interorgan flow of amino acids and organ-specific metabolism (1.5 h)**

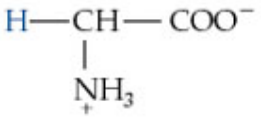
References

- **Gropper SS, Smith JL, Groff JL. Advanced Nutrition and Human Metabolism, 5th ed. Wadsworth: Belmont, 2009.**
- **Gropper SS, Smith JL, Groff JL. Advanced Nutrition and Human Metabolism, 4th ed. Wadsworth: Belmont, 2005.**
- **Groff JL, Gropper, SS. Advanced Nutrition and Human Metabolism, 3rd ed. Wadsworth Thompson Learning: Belmont, 2000.**
- **Linder MC. Nutritional Biochemistry and Metabolism: with Clinical Applications, 2nd ed. Elsevier: New York, 1991.**

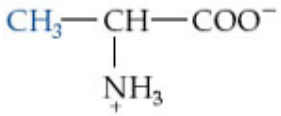
Table 7.1 Structural Classification of Amino Acids.

1. *With aliphatic side chains*

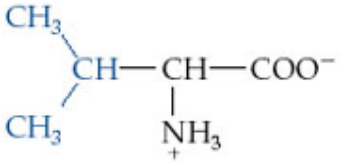
Glycine (Gly)



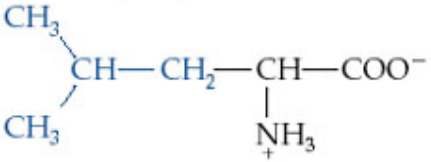
Alanine (Ala)



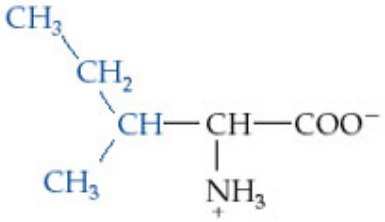
Valine (Val)



Leucine (Leu)

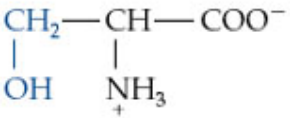


Isoleucine (Ile)

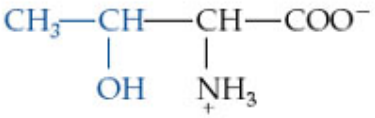


2. *With side chains containing hydroxylic (OH) groups**

Serine (Ser)

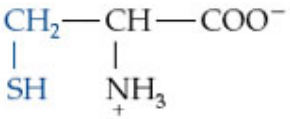


Threonine (Thr)

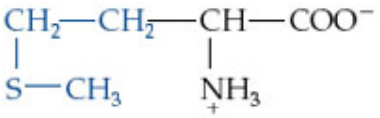


3. *With side chains containing sulfur atoms*

Cysteine (Cys)



Methionine (Met)



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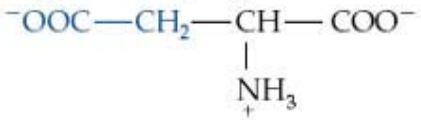
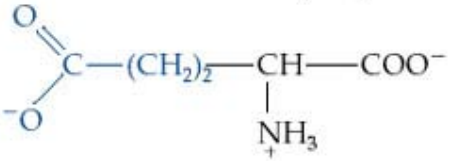
4. *With side chains containing acidic groups or their amides*

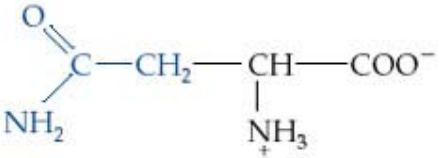
Aspartic acid (Asp)



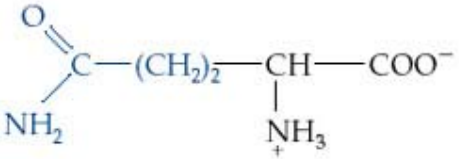
Glutamic acid (Glu)



Asparagine (Asn)

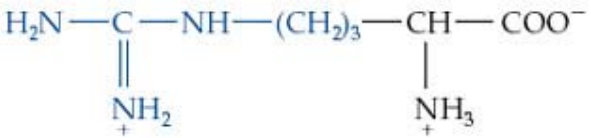


Glutamine (Gln)

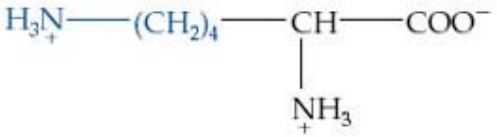


5. *With side chains containing basic groups*

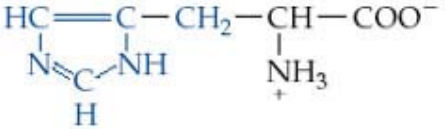
Arginine (Arg)



Lysine (Lys)

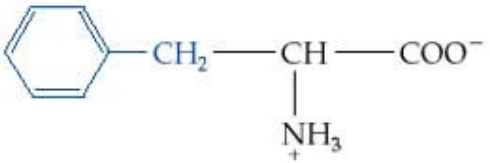


Histidine (His)

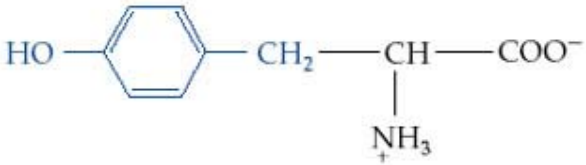


6. *With side chains containing aromatic ring*

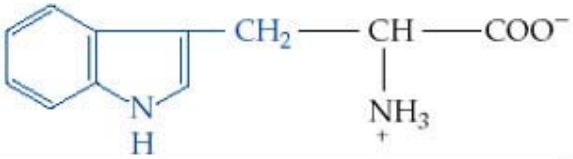
Phenylalanine (Phe)



Tyrosine (Tyr)



Tryptophan (Trp)



* Although tyrosine contains a hydroxyl group, it is classified as an amino acid containing an aromatic ring (see Group 6).

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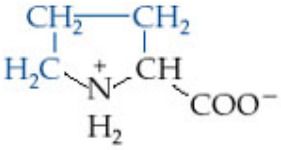
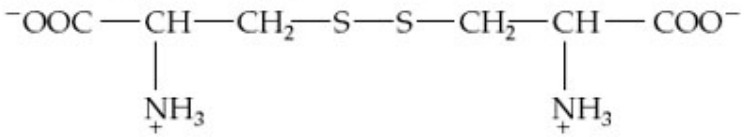
Table 7.1 *(Continued)*

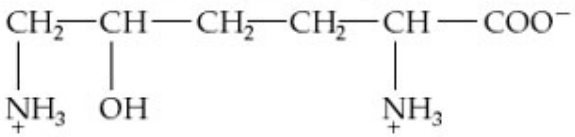
7. *Imino acids*
Proline (Pro)



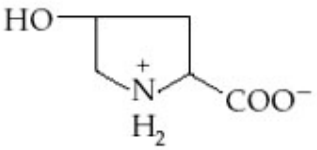
8. *Amino acids formed posttranslationally*
Cystine (Cys-S-S-Cys)



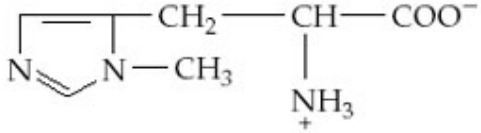
Hydroxylysine (Hyl)



Hydroxyproline (Hyp)



3-methylhistidine (3-meHis)



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Essential (indispensable) amino acids (EAAs)

- **BCAAs: leucine, isoleucine, valine (branched-chain amino acids; BCAAs)**
- **basic AAs: lysine (totally indispensable), arginine (conditional), histidine (infant)**
- **aromatic AAs: tryptophan, phenylalnine**
- **hydroxylic AA: threonine (totally indispensable)**
- **AA with sulfur atom: methionine**

Table 7.2 Some Enzymes Responsible for the Digestion of Protein

Zymogen	Enzyme or Activator	Enzyme	Site of Activity	Substrate (peptide bonds adjacent to)
Pepsinogen	HCl or pepsin →	Pepsin	Stomach	Most amino acids, including aromatic, dicarboxylic, leu, met
Trypsinogen	Enteropeptidase → or Trypsin	Trypsin	Intestine	Basic amino acids
Chymotrypsinogen	Trypsin →	Chymotrypsin	Intestine	Aromatic amino acids, met, asn, his
Procarboxypeptidases	Trypsin →	Carboxypeptidase A	Intestine	C-terminal neutral amino acids
		B		C-terminal basic amino acids
		Aminopeptidases	Intestine	N-terminal amino acids

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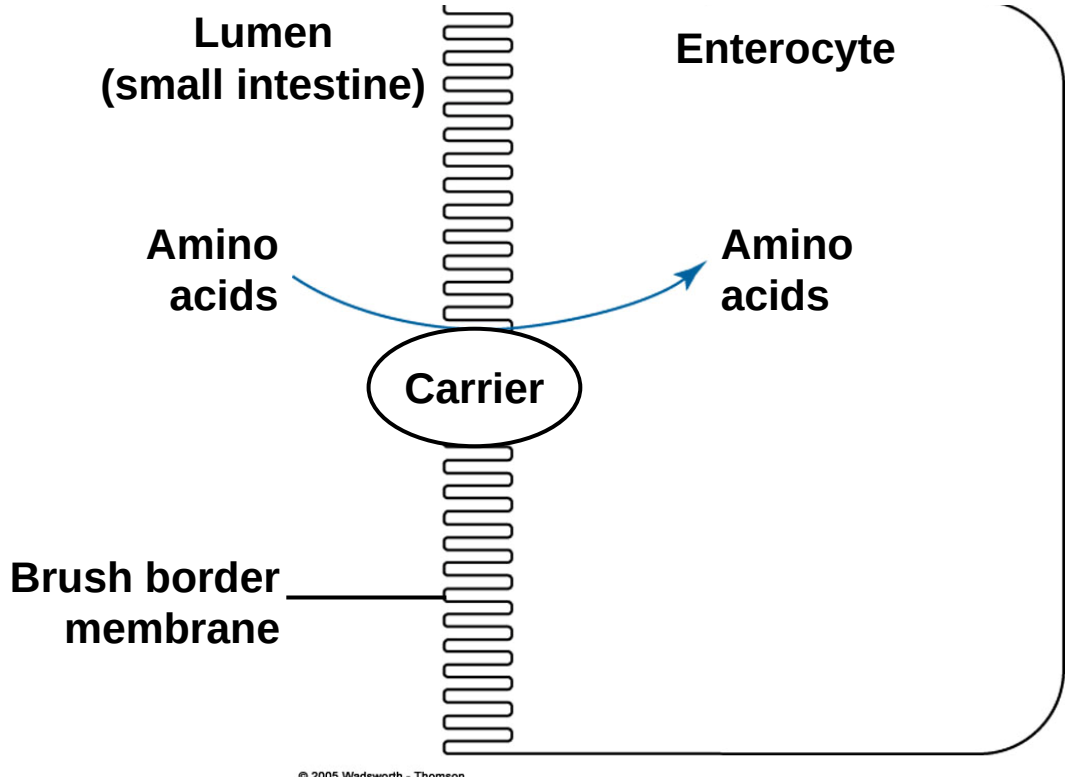
Amino acid absorption

- **Brush border** membrane absorption

  Na^+-dependent active transport

  Na^+-independent active transport



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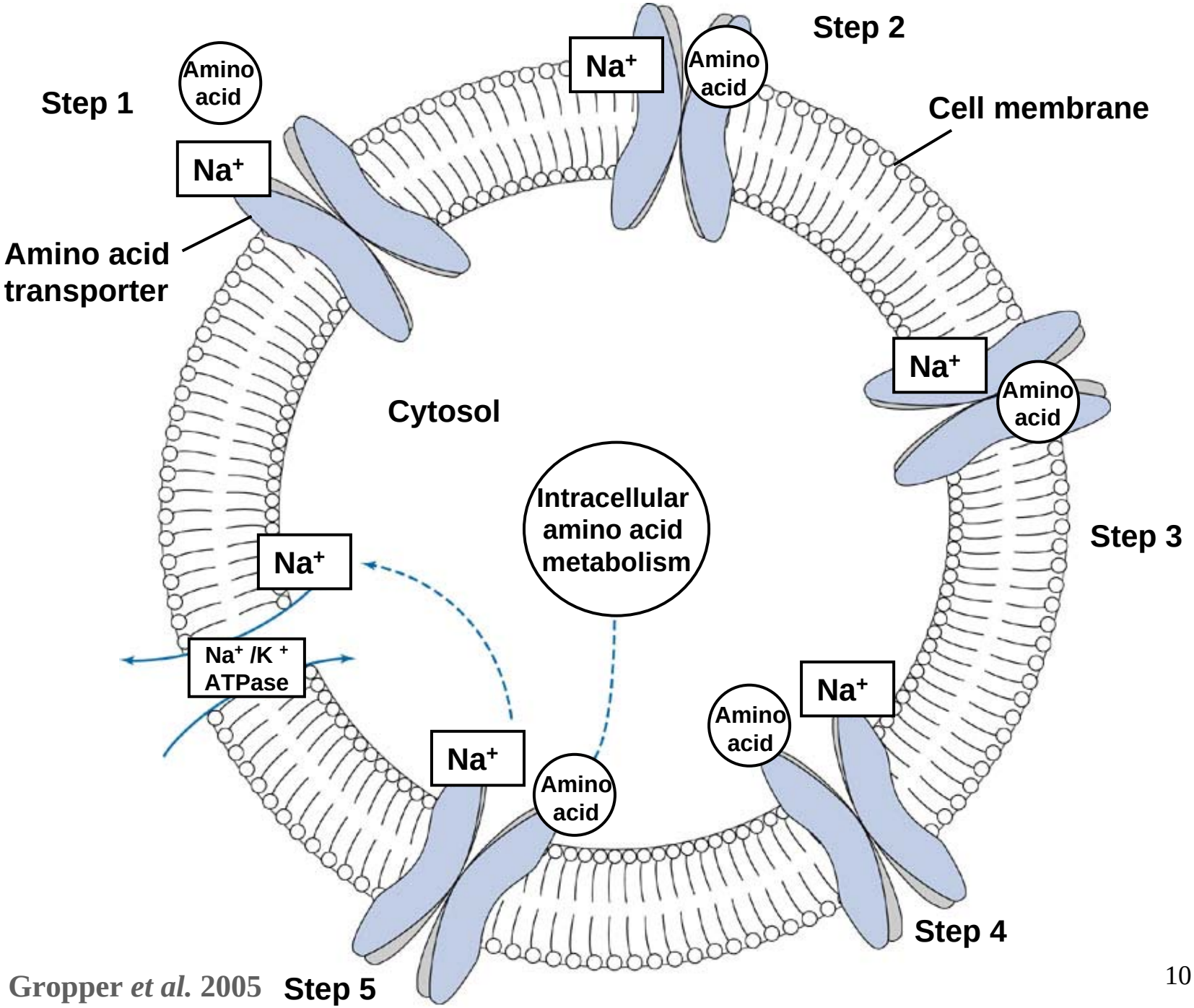

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Table 7.3 Some Systems Transporting Amino Acids across the Intestinal Cell Brush Border Membrane

Amino Acid Transport Systems	Sodium Required	Examples of Substrates Carried
L	No	Leucine, other neutral amino acids
B	Yes	Phenylalanine, tyrosine, tryptophan, isoleucine, leucine, valine
IMINO	Yes	Proline, glycine
y^{+} *	No	Basic amino acids
X^{-}_{AG}	Yes	Aspartate, glutamate
$B^{o,+}$	Yes	Most neutral and basic amino acids
$b^{o,+}$	No	Most neutral and basic amino acids

*In the presence of sodium, neutral amino acids can competitively inhibit the y^{+} system and participate in exchange reactions with the basic substrates [3].

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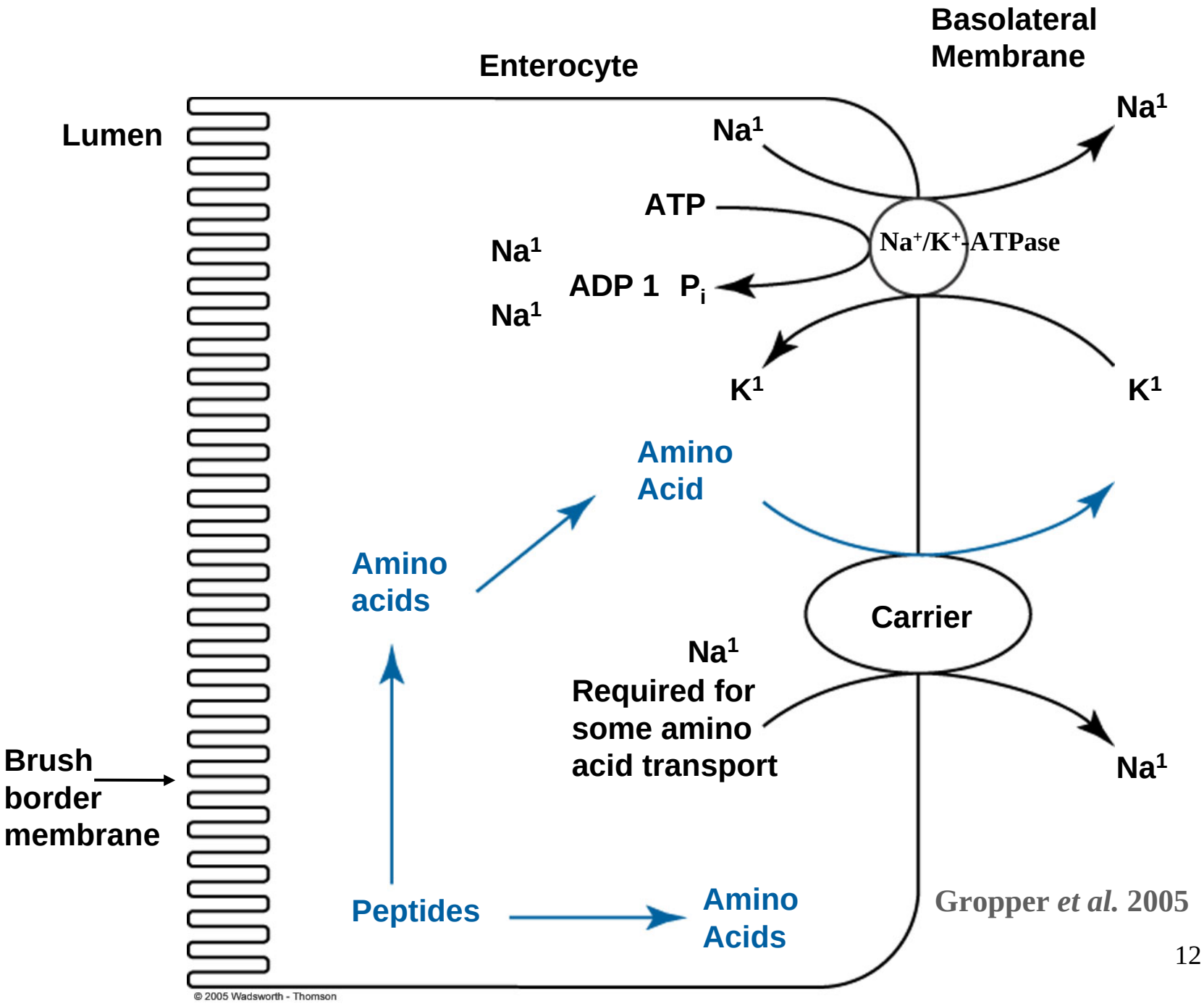


Gropper *et al.* 2005

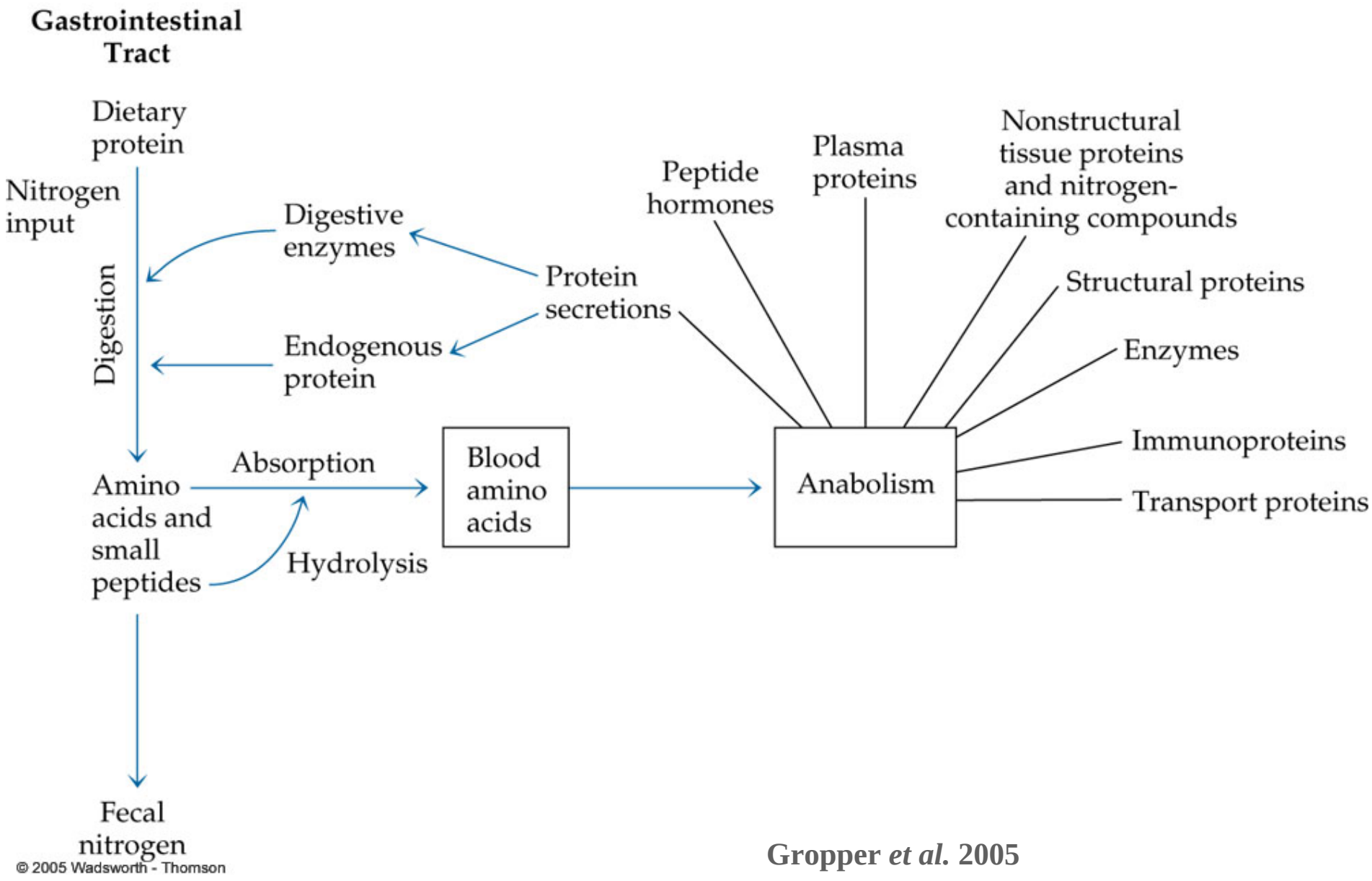
Table 7.4. Some Systems Transporting Amino Acids across the Intestinal Cell Basolateral Membrane

Amino Acid Transport System	Sodium Required	Examples of Substrates Carried
L	No	Leucine, other neutral amino acids
y^+	No	Basic amino acids
$b^{o,+}$	No	Neutral and basic amino acids
X^-_{AG}	Yes	Aspartate and glutamate
A	Yes	Alanine, other short-chain, polar, neutral amino acids
ASC	Yes	Alanine, cysteine, serine, other three- and four-carbon amino acids
asc	No	Same substrates as ASC

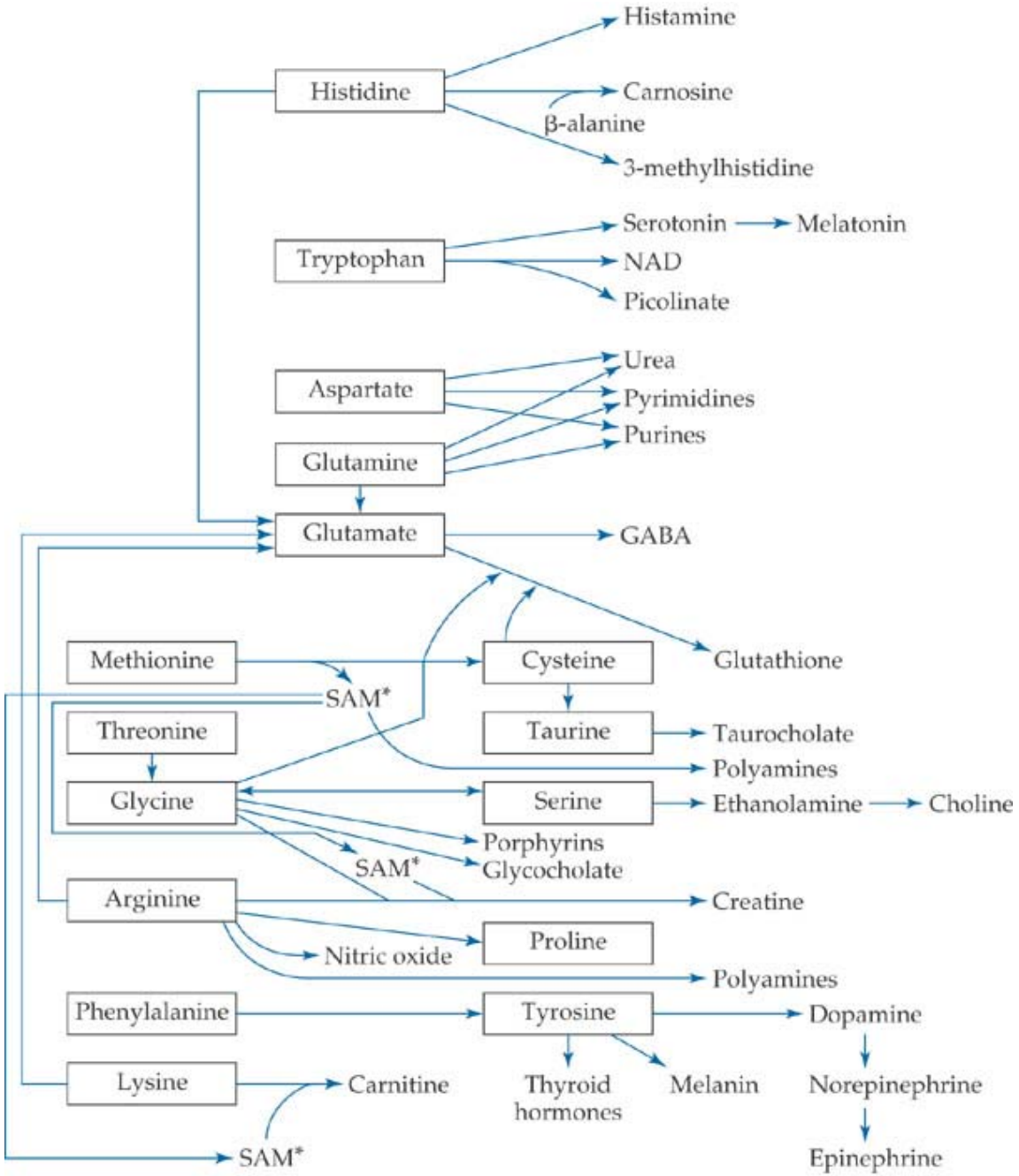
Gropper *et al.* 2005

Amino acid absorption

- most rapidly absorbed AAs
- branched-chain AAs > smaller AAs
- neutral AAs > dibasic or dicarboxylic AAs
- EAAs > NEAAs
- Met, Leu, Ile, Val
- Most slowly absorbed AAs
- Glu, Asp



Gropper *et al.* 2005



*SAM = s-adenasyl methionine.

Gropper *et al.* 2005

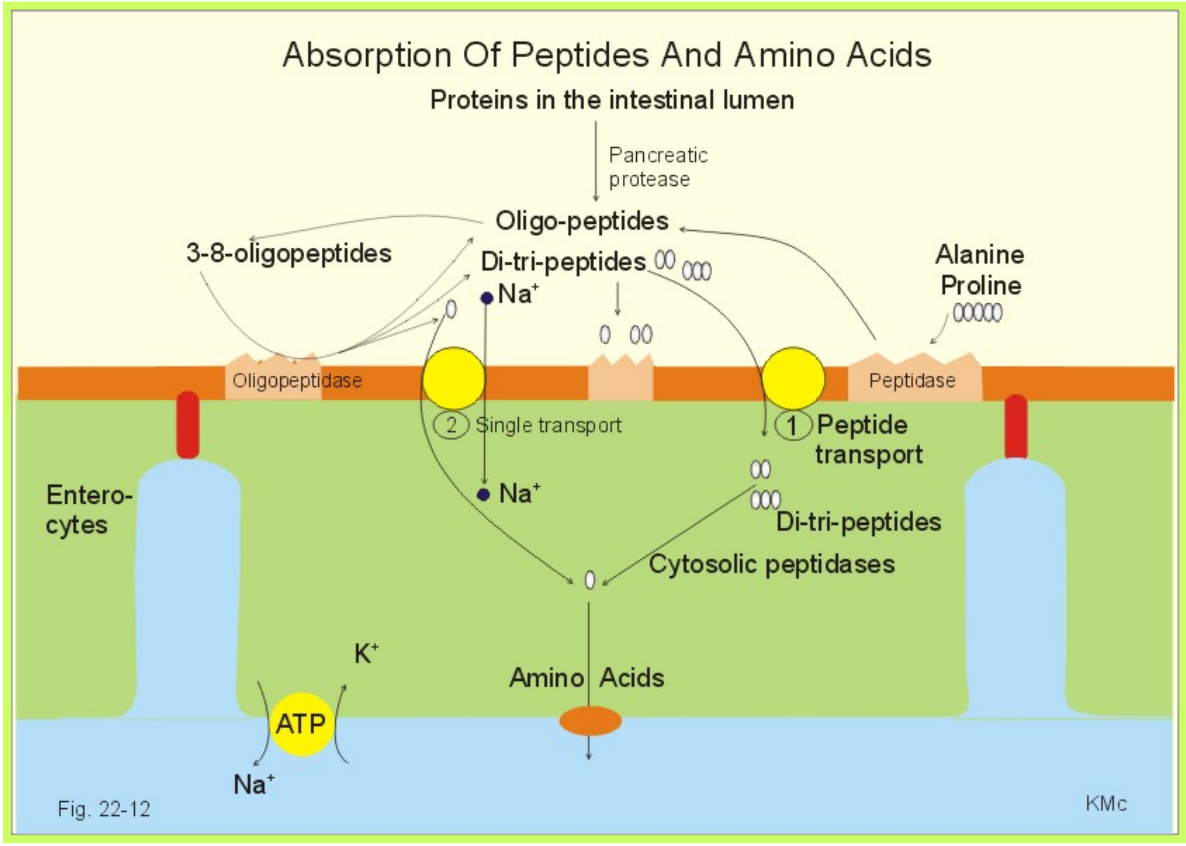
- 何種胺基酸在人體小腸吸收較快？

(1) Glycine

(2) Methionine

(3) Tyrosine

(4) Arginine



http://www.mfi.ku.dk/ppaulev/chapter22/kap%2022.htm

Transaminase (aminotransferase)

- **alanine aminotransferase (ALT)**

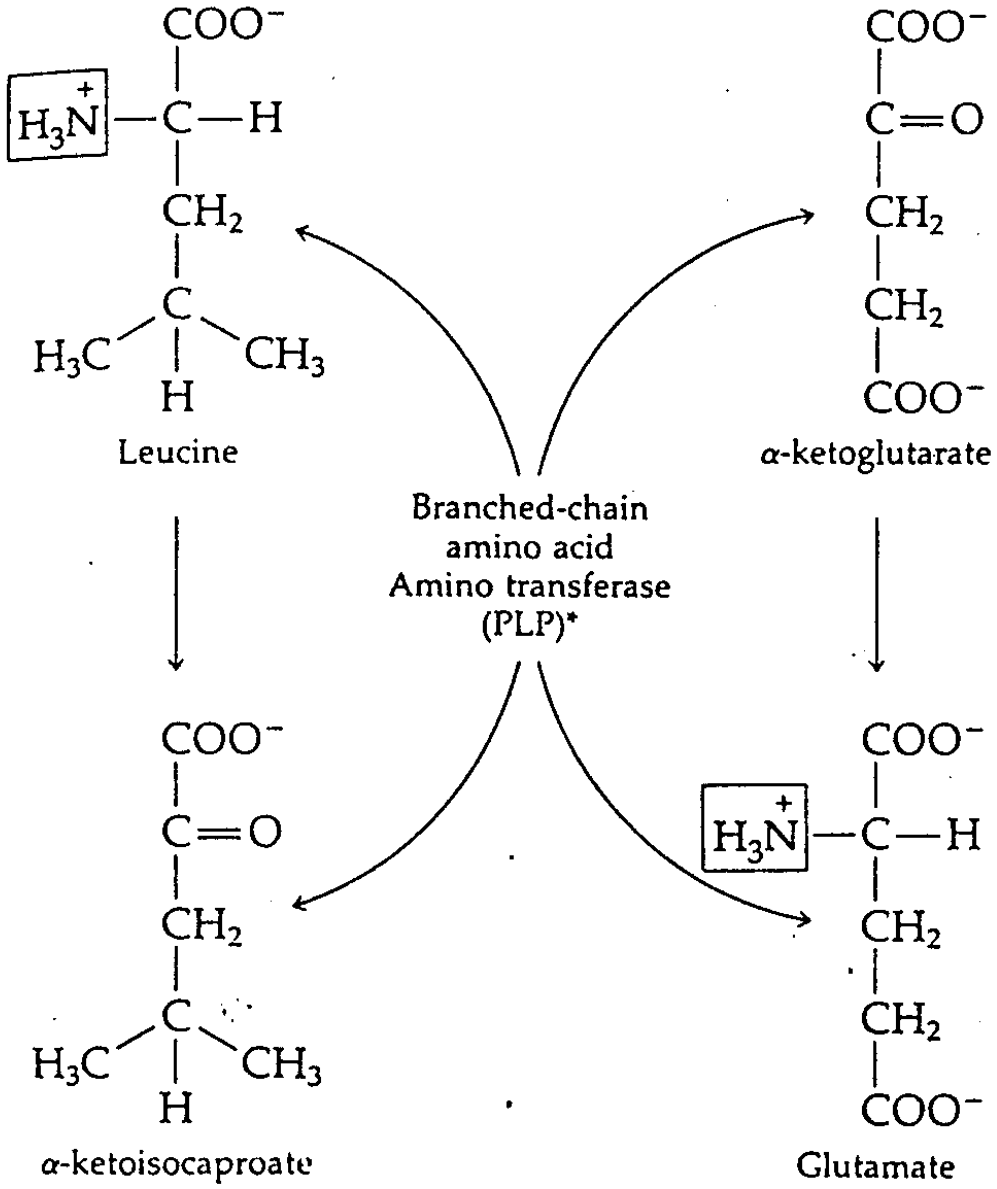
  glutamate pyruvate transaminase (GPT)

  higher concentrations in liver, heart, kidney

- **aspartate aminotransferase (AST)**

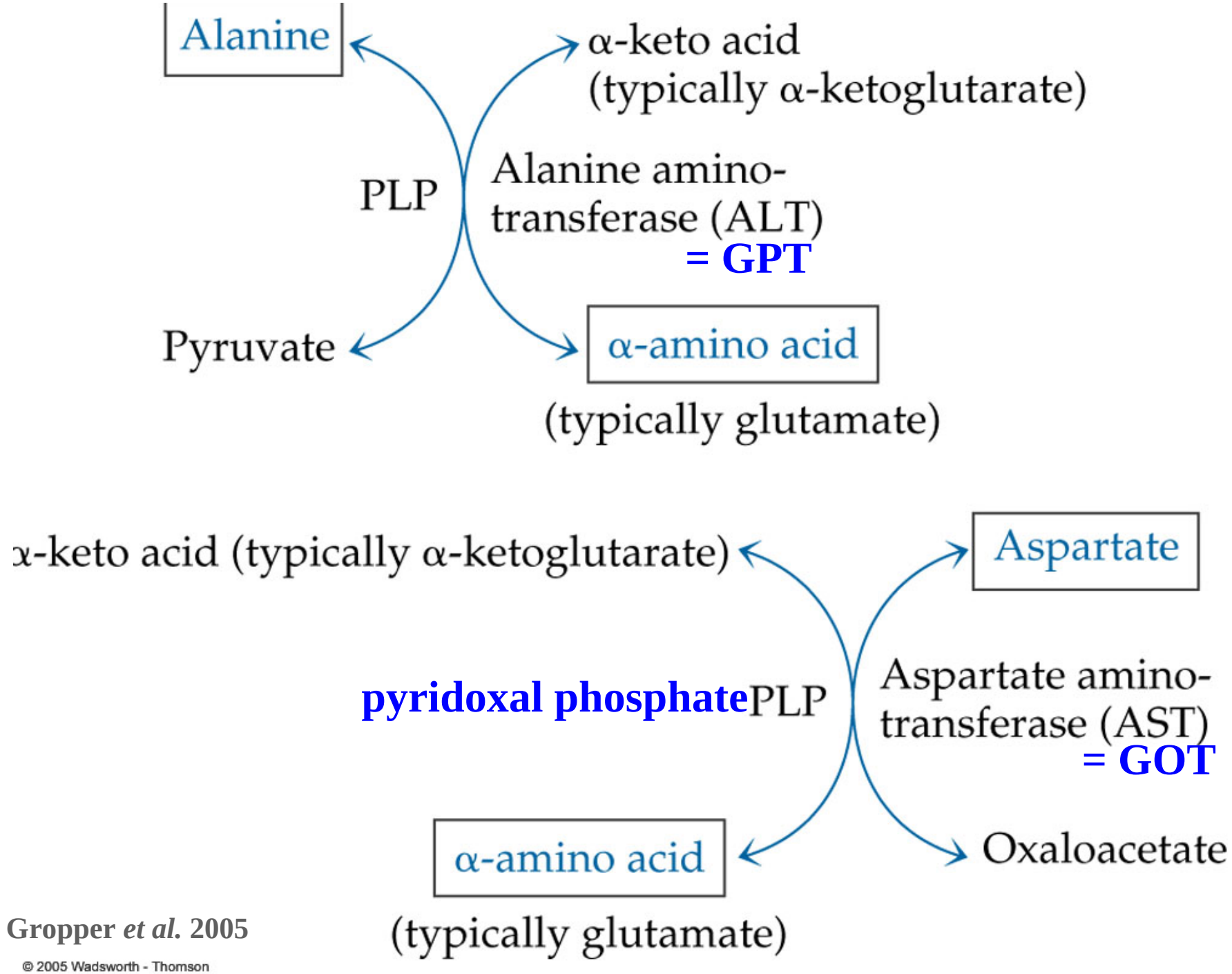
  glutamate oxaloacetate transaminase (GOT)

  higher concentrations in heart, liver, muscles

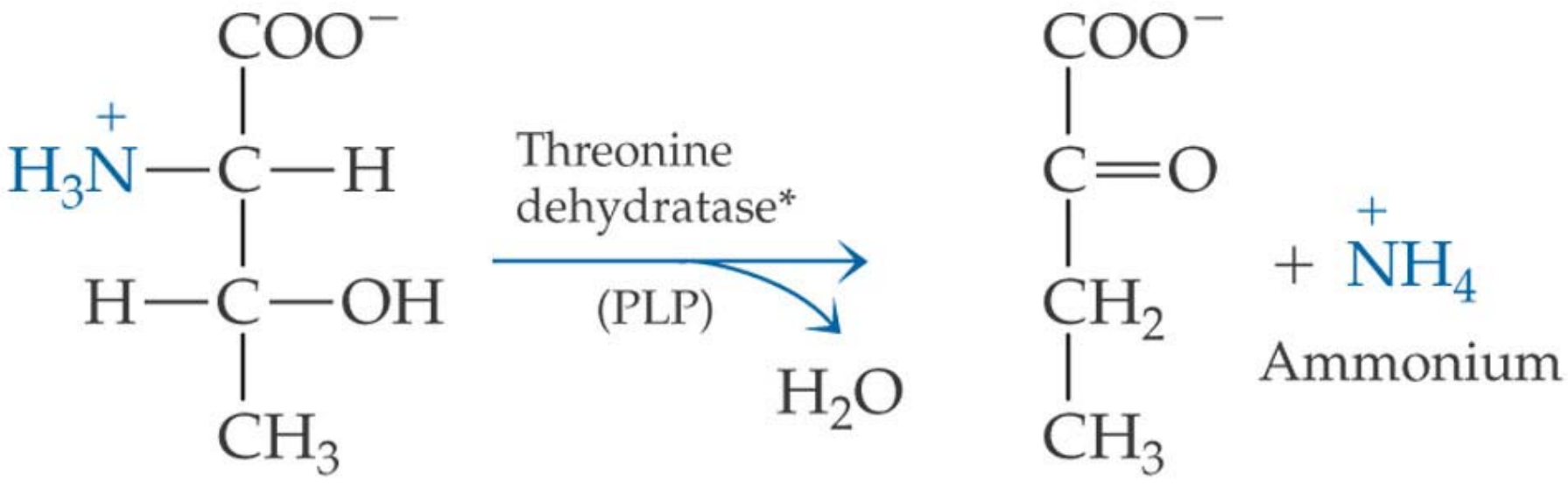


(a) *Transamination reaction*: Amino transferases transfer an amino group from an amino acid to an α-keto acid. *PLP, pyridoxal phosphate.

Groff and Gropper. 2000

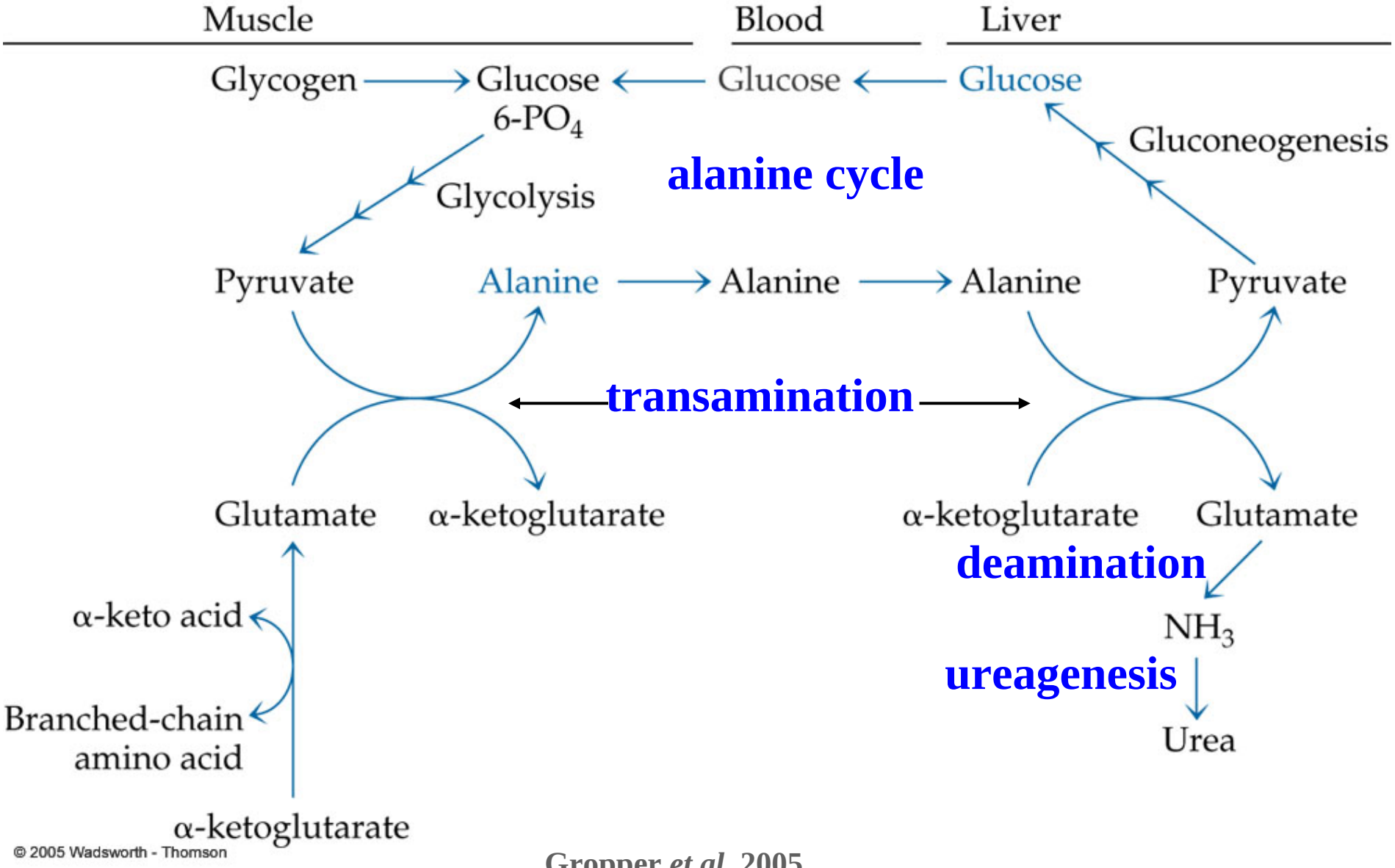


Gropper *et al.* 2005

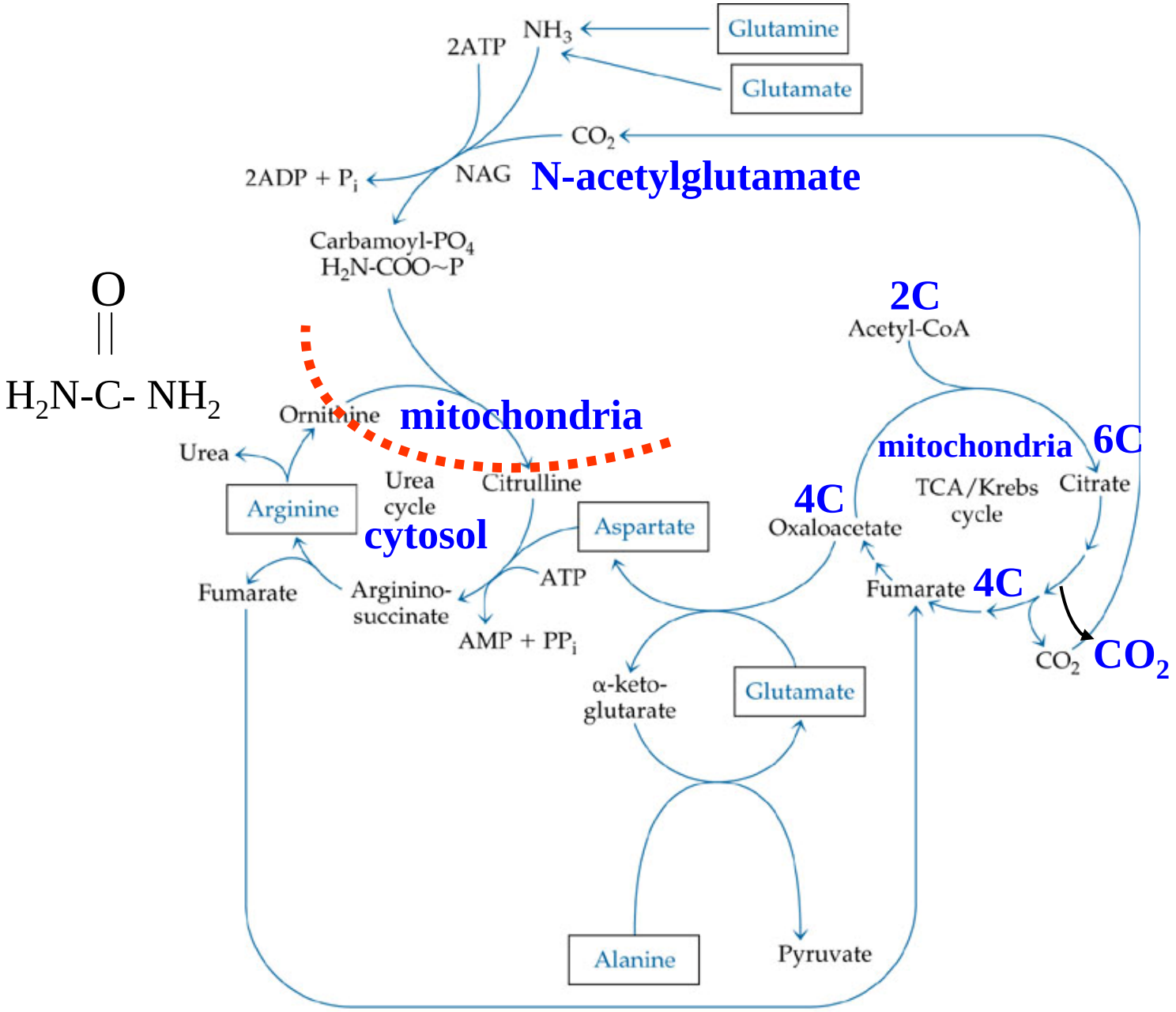


*The enzyme is called *dehydratase* rather than *deaminase* because the reaction proceeds by loss of elements of water.

Gropper *et al.* 2005



Gropper *et al.* 2005



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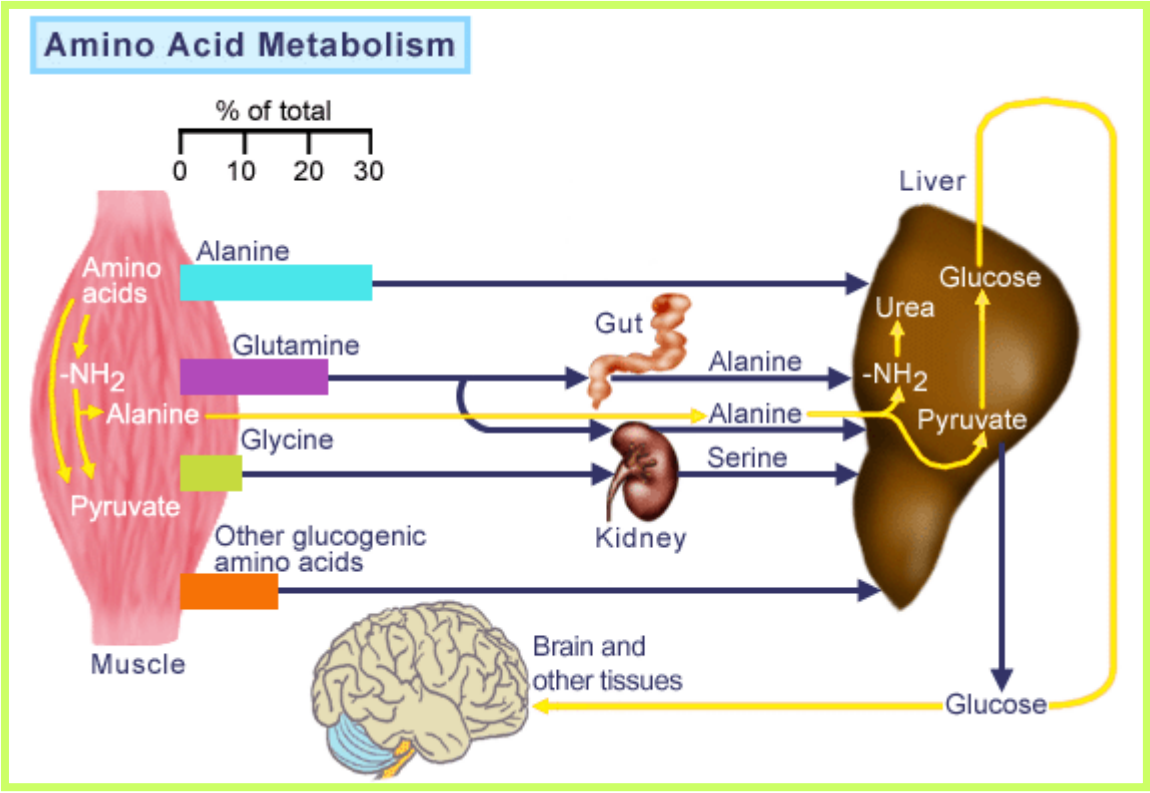
- 何者<u>不是</u>人體代謝胺基酸的生化反應？

(1) Cori cycle

(2) Deamination

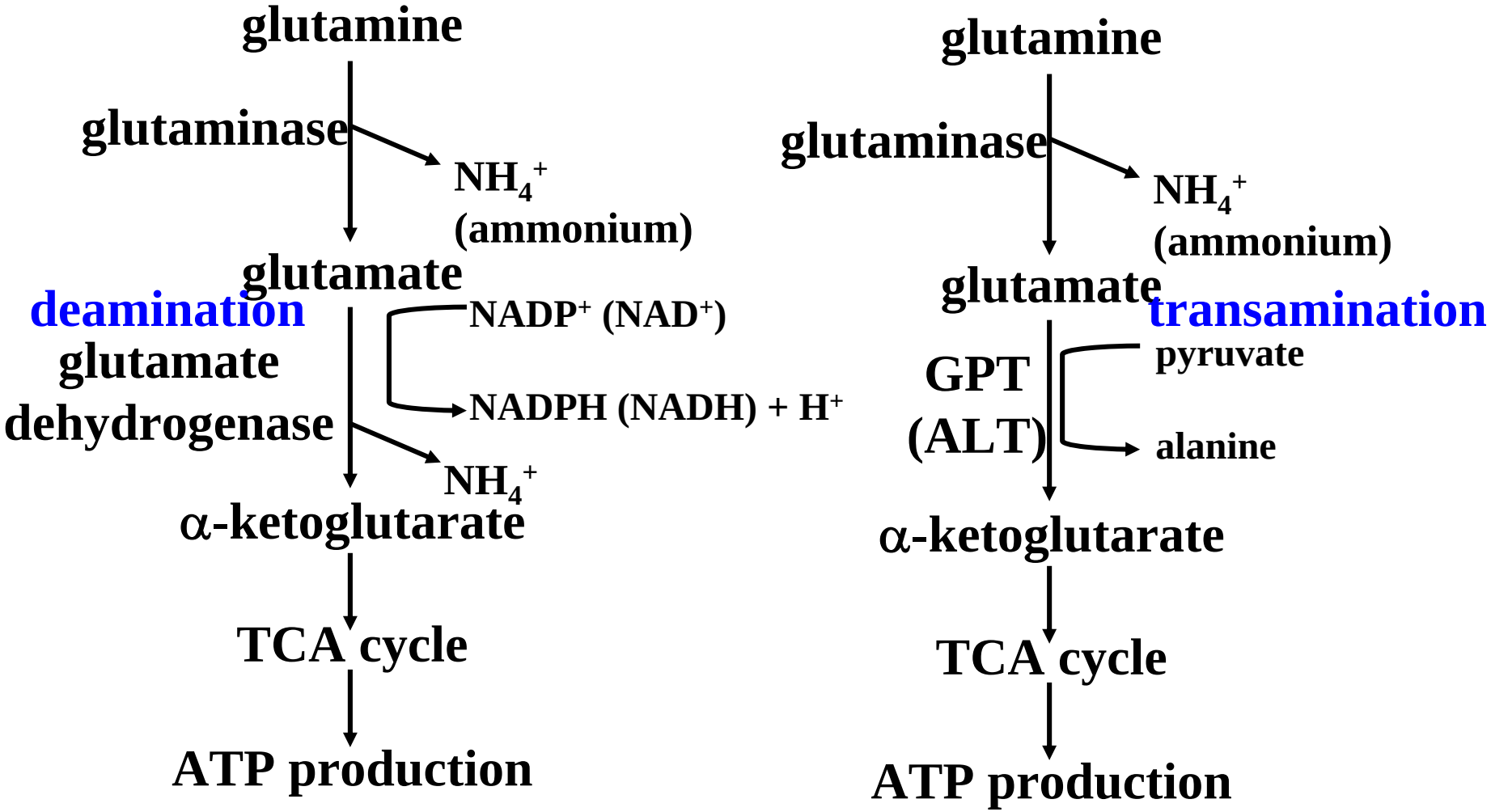
(3) Glucose-alanine cycle

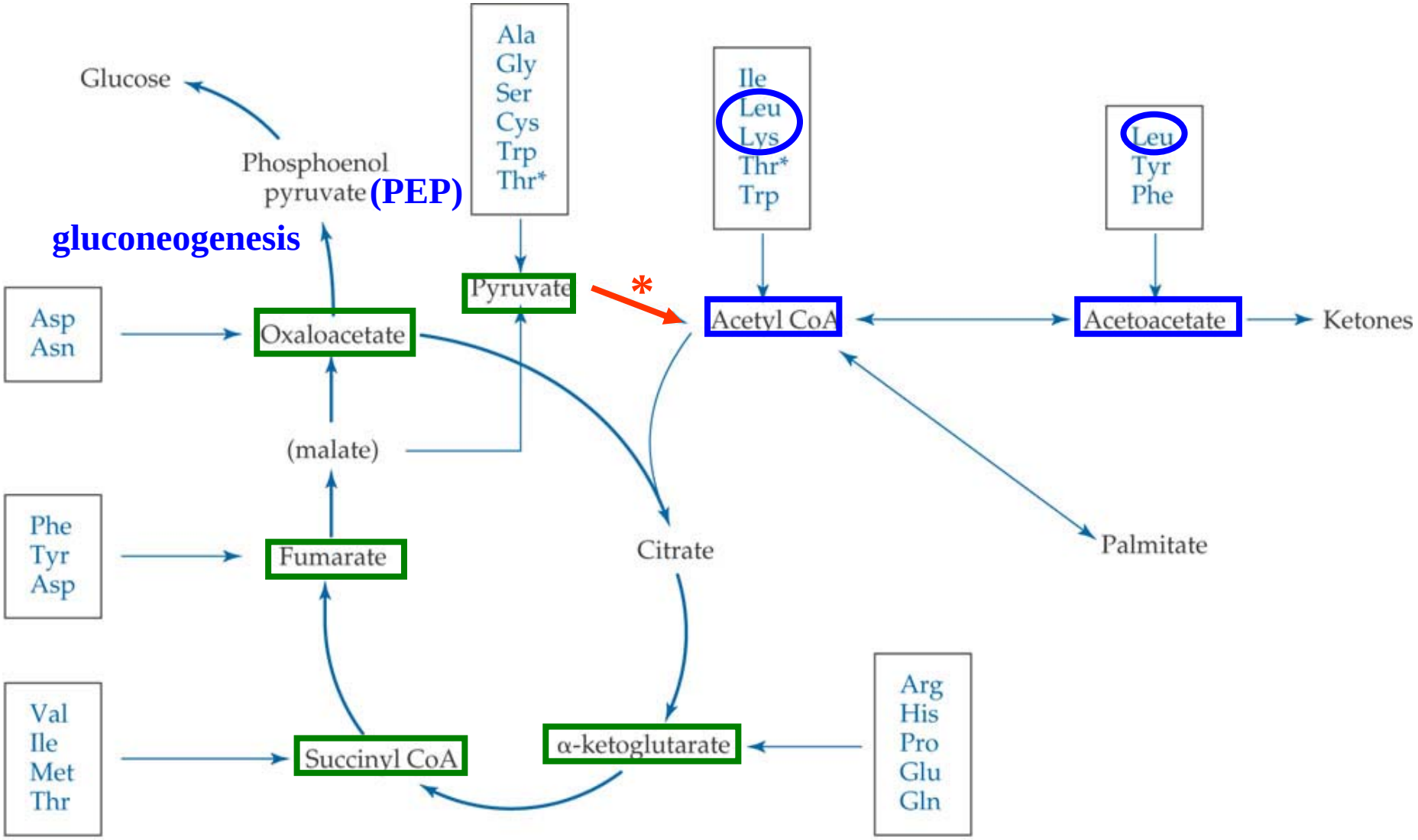
(4) Urea cycle



http://www.mmi.mcgill.ca/mmimediasampler2002/

Glutamine utilization in intestine





*Physiological contribution unclear

***irreversible**
pyruvate dehydrogenase

Ketogenic: Leu, Lys
Partially ketogenic and glucogenic
Glucogenic

Gropper *et al.* 2005

Amino acid metabolism in skeletal muscles

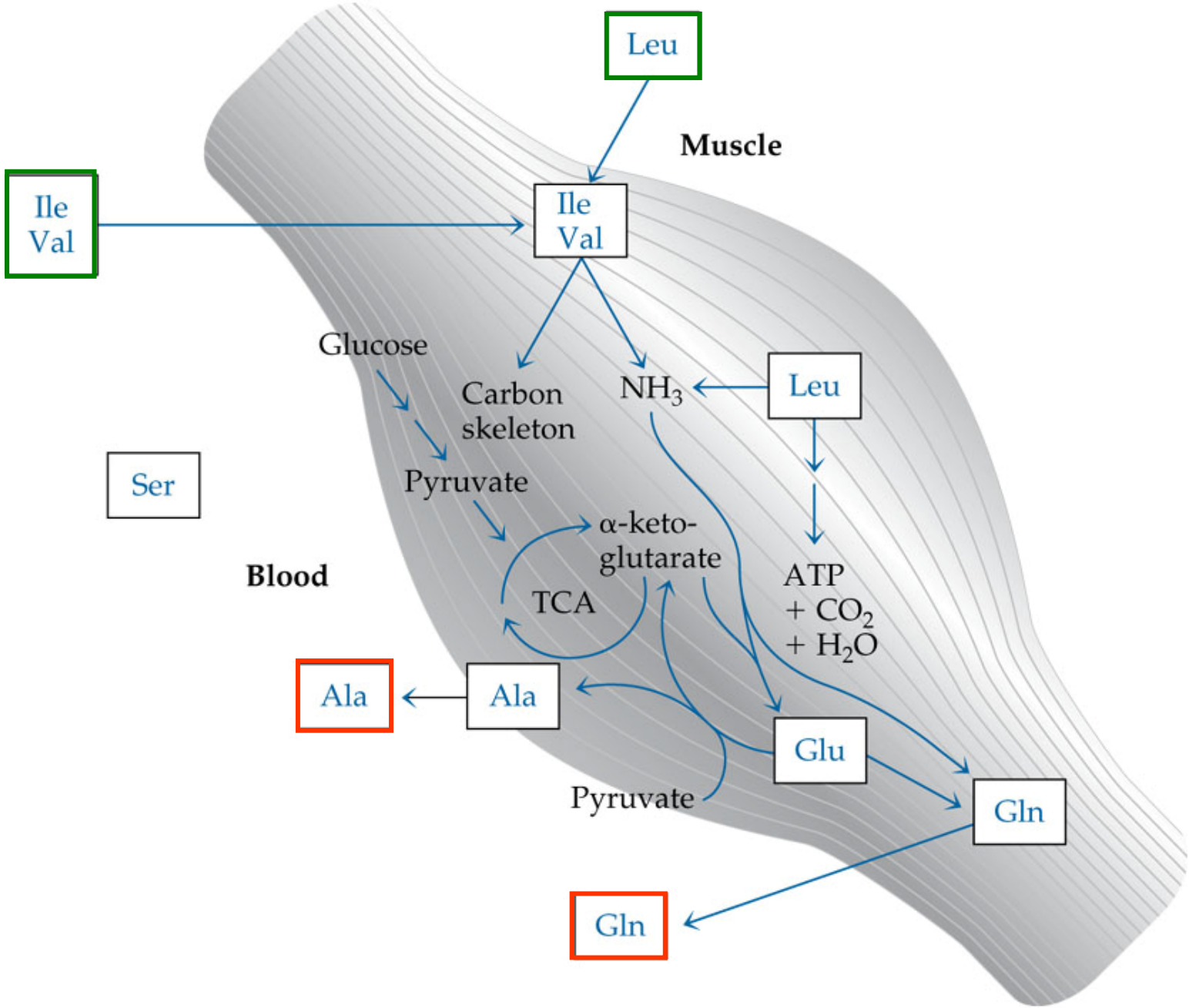
- **synthesized de novo and released into the blood**

  alanine (ala), glutamine (gln)

- **catabolized in skeletal muscles for utilization**

  aspartate (asp), asparagine (asn), glutamate (glu),

  leucine (leu), isoleucine (ile), valine (val)



Gropper *et al.* 2005

Amino acid metabolism in kidney

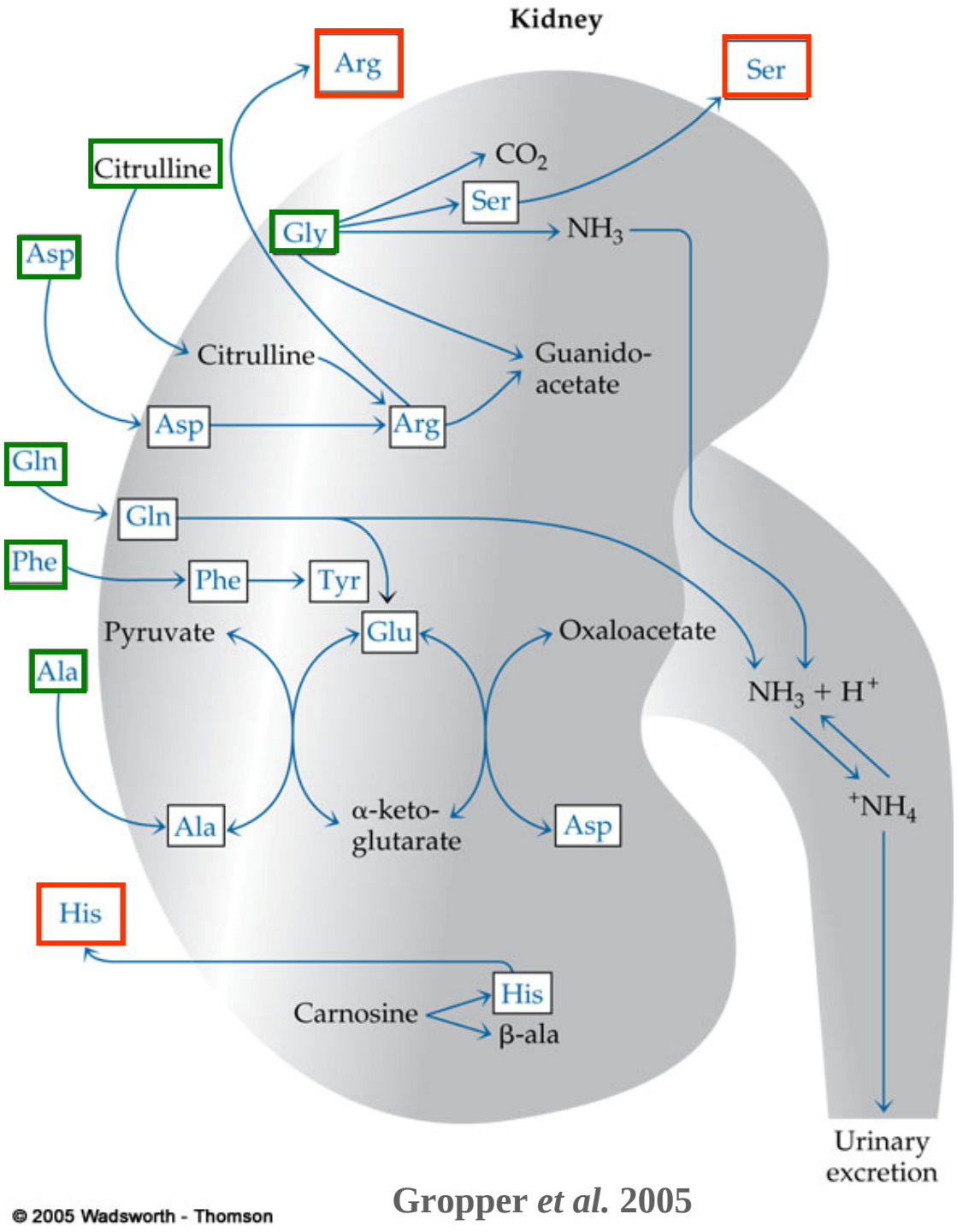
- **synthesized de novo and released into the blood**

  arginine (arg), histidine (his), serine (ser)

- **catabolized in kidney for utilization**

  aspartate (asp), glutamine (gln), phenylalanine,

  alanine (ala), glycine, citrulline (cit)



Gropper *et al.* 2005

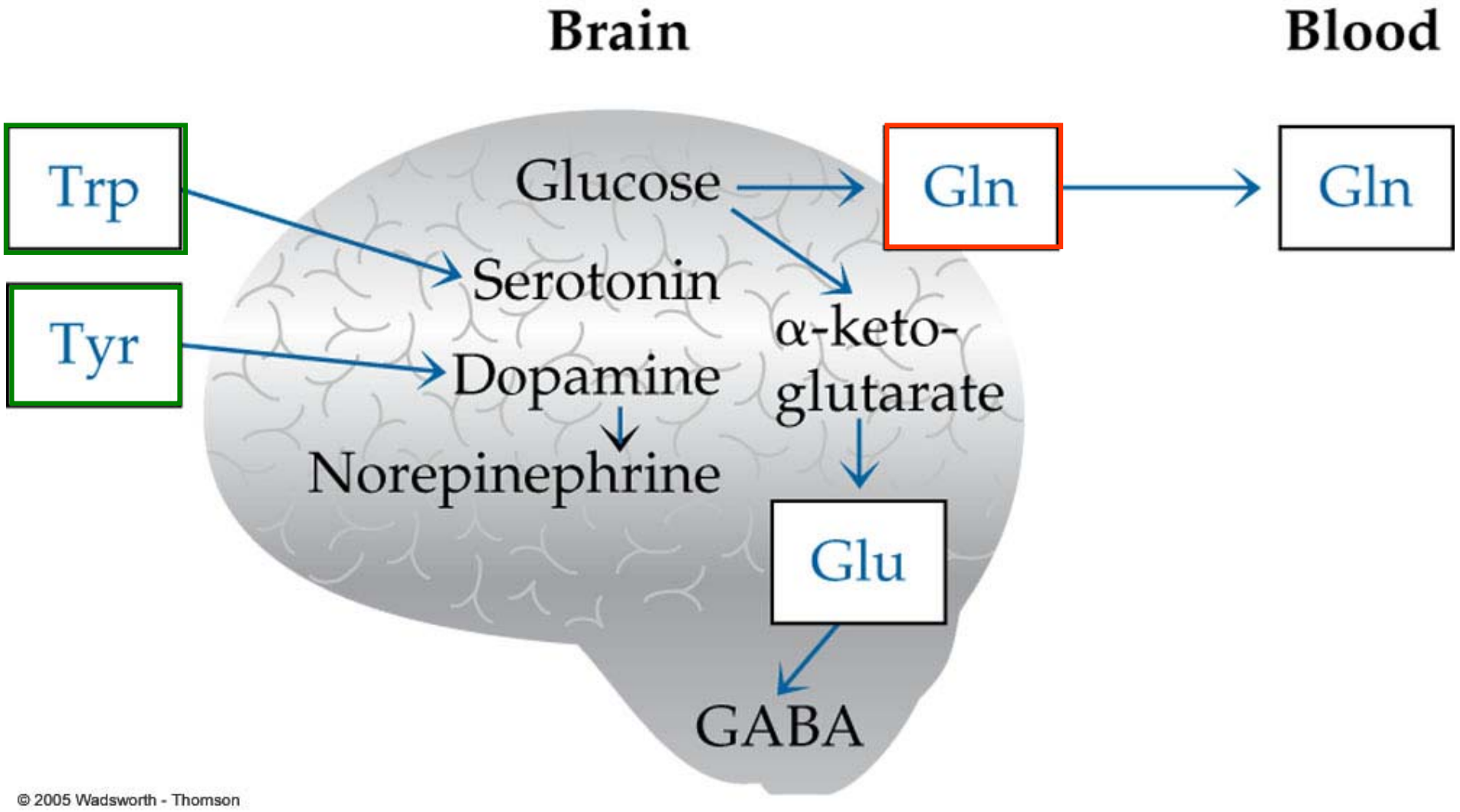
Amino acid metabolism in brain

- **synthesized de novo and released into the blood**

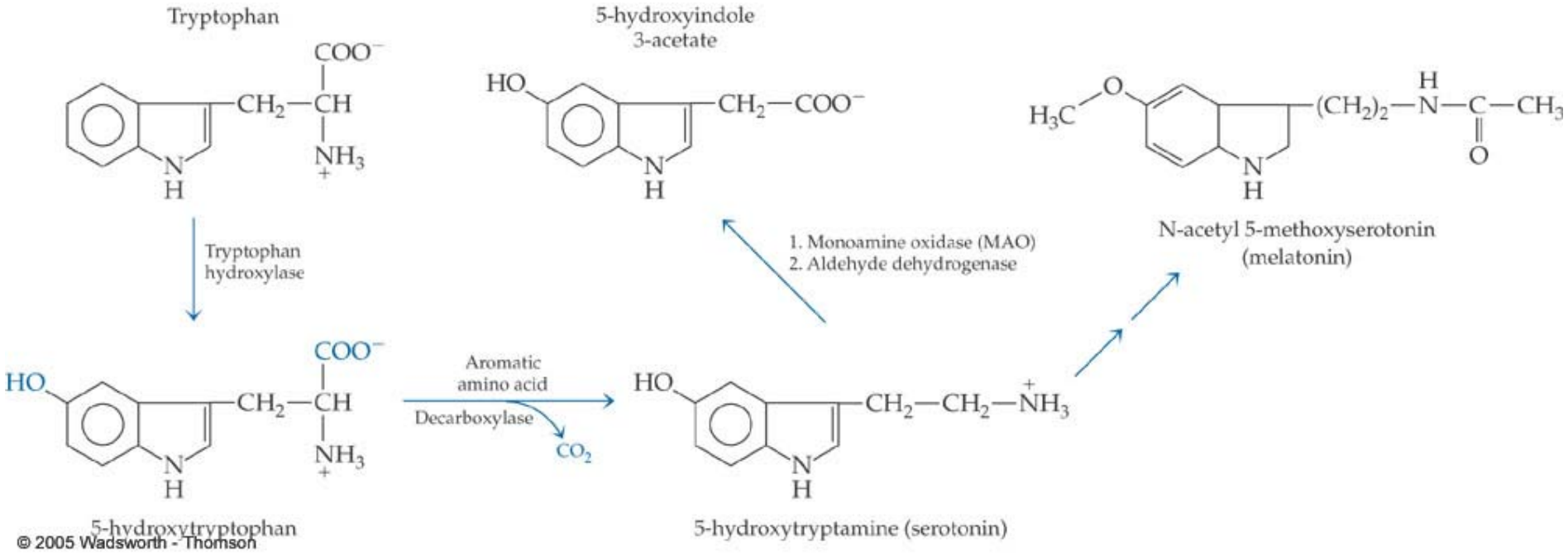
  glutamine (gln)

- **catabolized in brain for utilization**

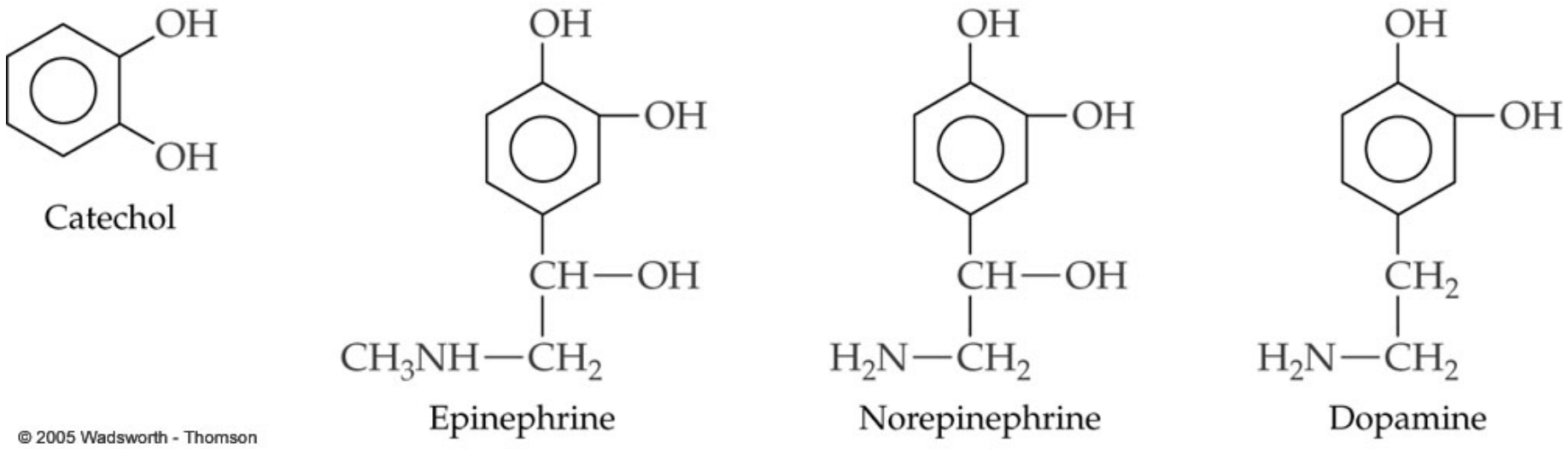
  tryptophan (trp), tyrosine (tyr)

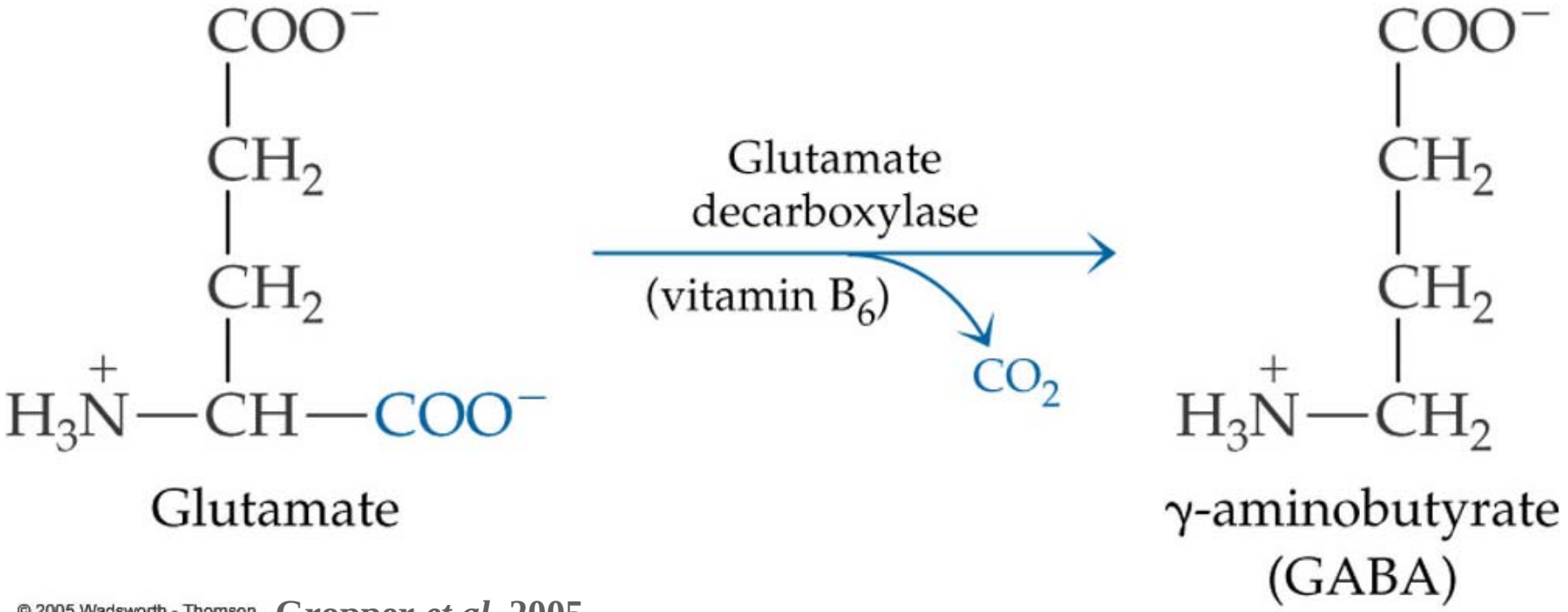


Gropper *et al.* 2005

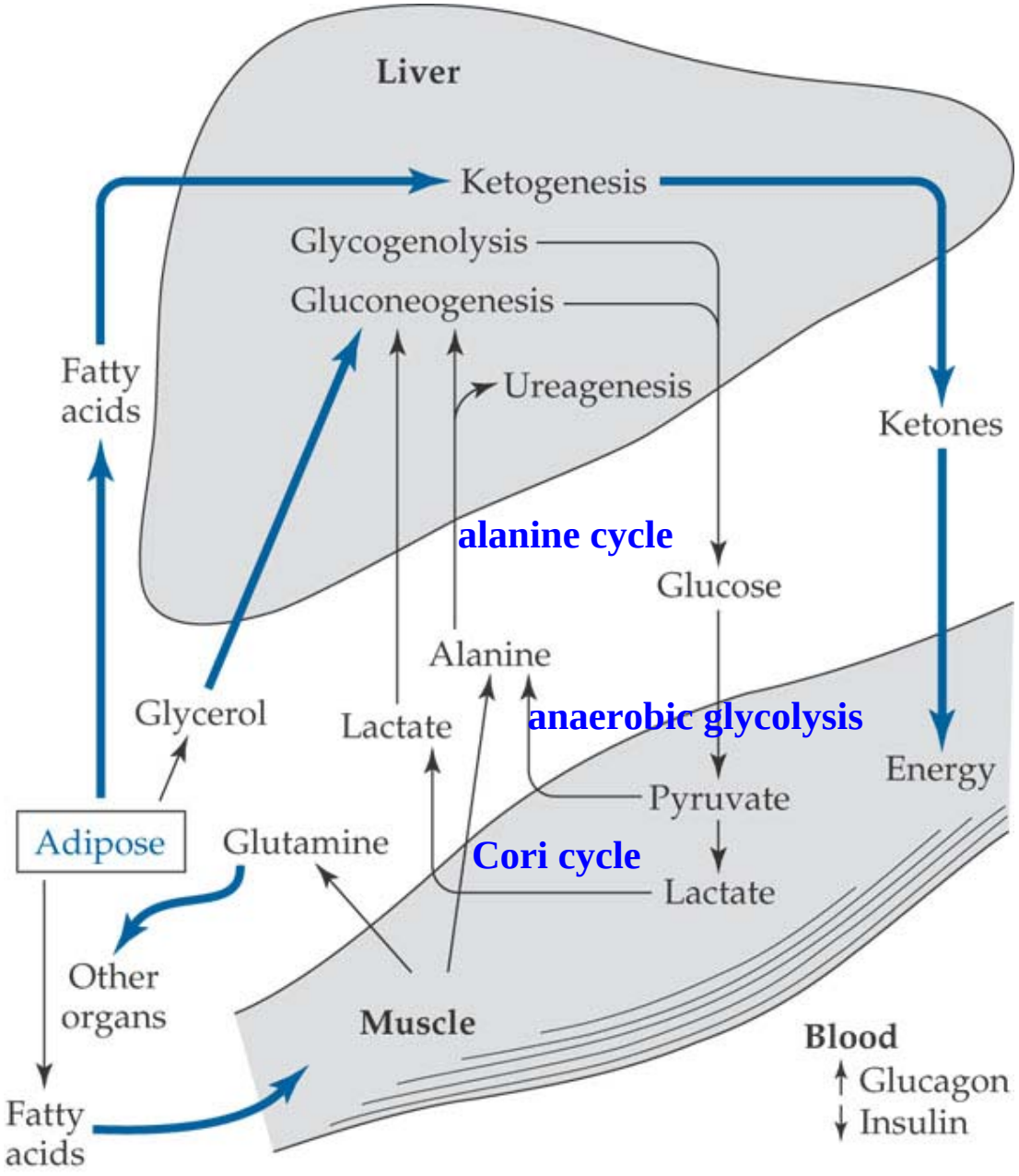


Gropper *et al.* 2005

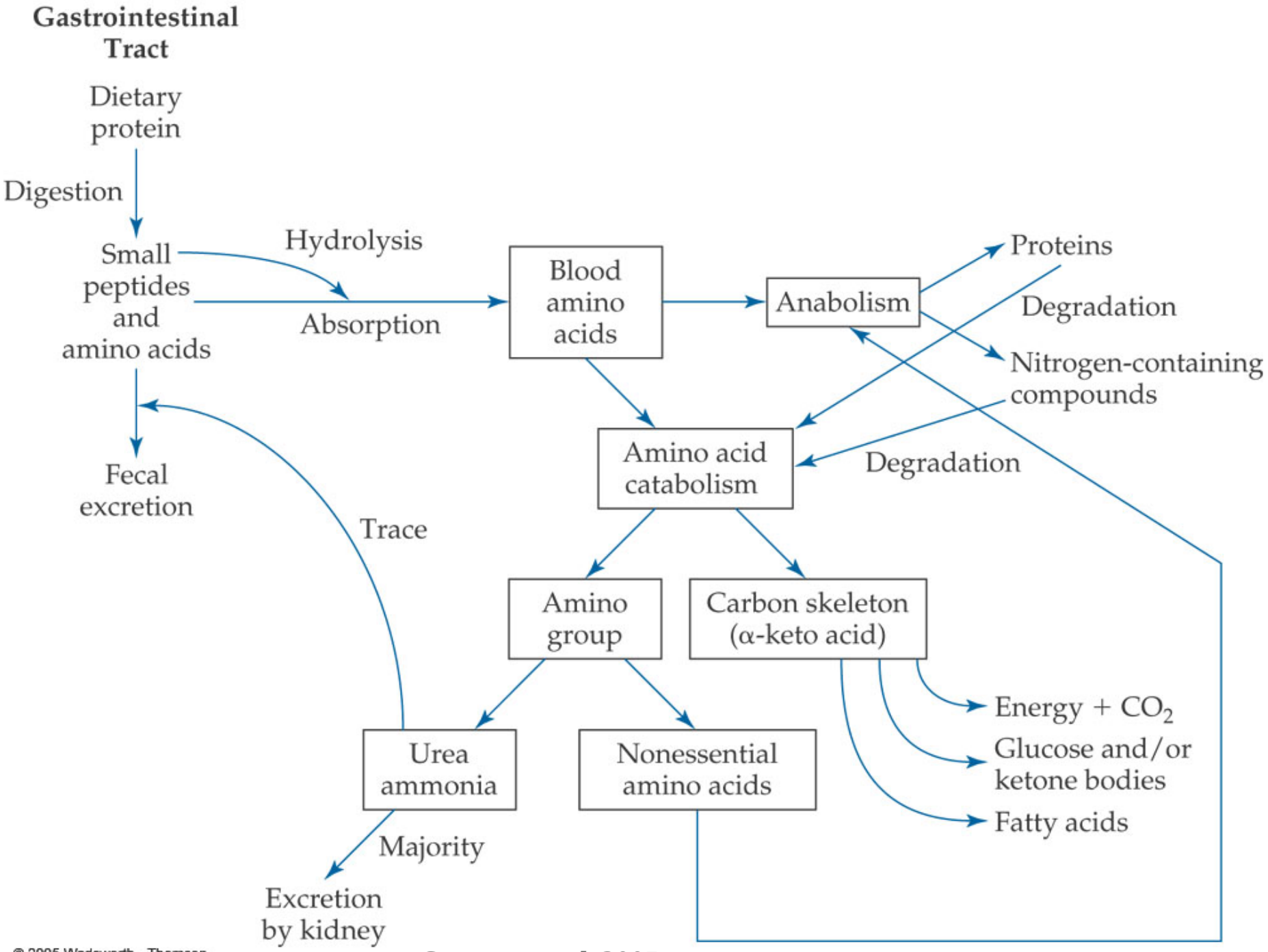




 Gropper *et al.* 2005



(a) Adapted starvation **Gropper *et al.* 2005**



Gropper *et al.* 2005

Table 7.5 Nitrogen-Containing Waste Products Excreted in the Urine

Compound	Approximate Amounts (g) Excreted per Day
Urea	5–20
Creatinine	1–1.8
Uric acid	0.3–1
Ammonia	0.4–1

Gropper *et al.* 2005

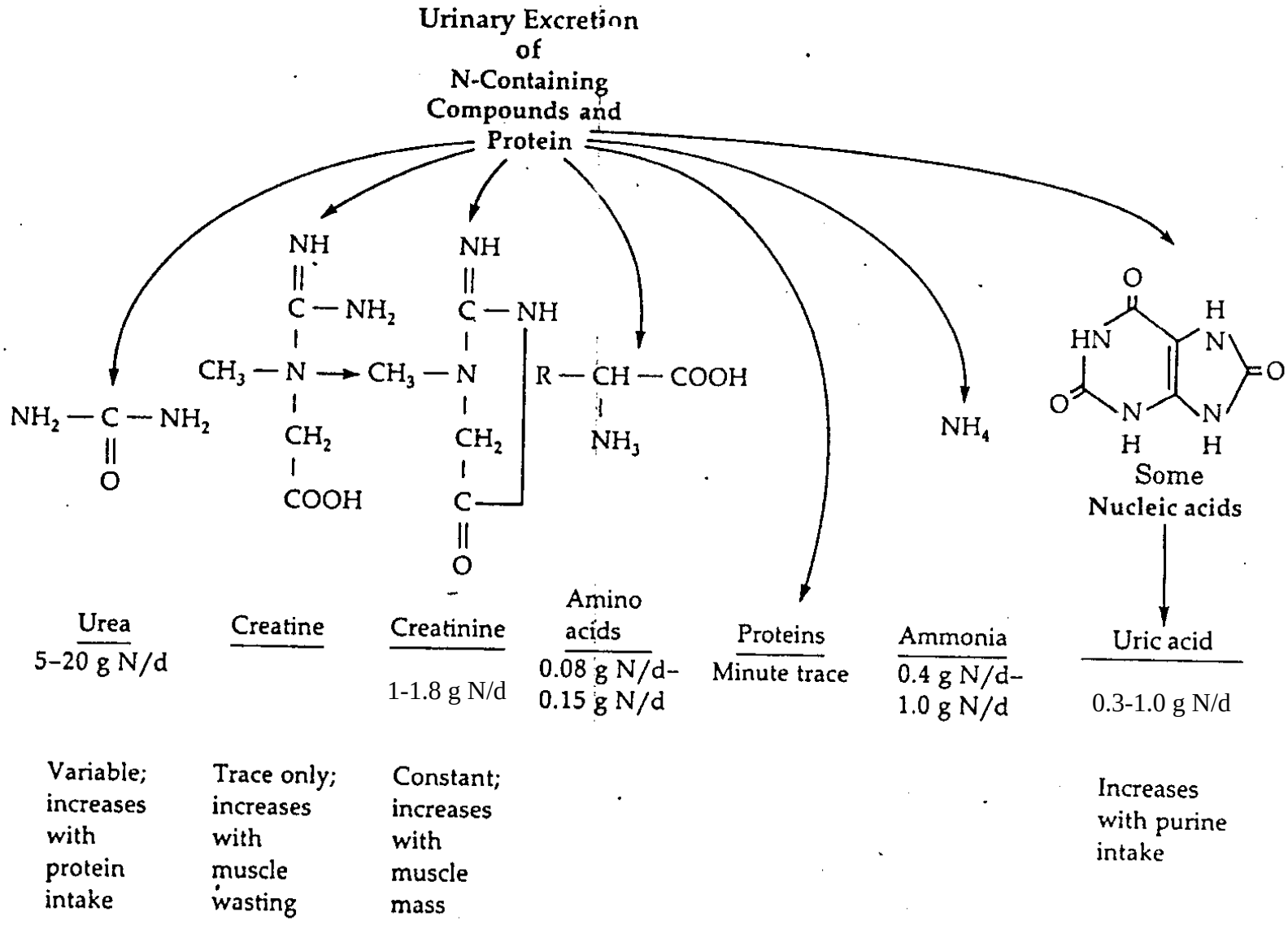


FIGURE 7.23 Nitrogenous wastes in normal urine. *(Reproduced with permission from W.C. McMurray, Essentials of Human Metabolism, 2/e, 1983, Harper & Row, p. 261.)*

Summary

- **The amino acids comprising the pools are used in a variety of ways.**
- **The liver is the primary site of amino acid metabolism. Of particular significance is the metabolism of branched-chain amino acids in skeletal muscles and the production of the ammonium ion in the kidney.**
- **Glutamate, glutamine, and alanine play the important roles in various metabolic pathways for amino acids.**