Roles of amino acids in the regulation of food intake by animals

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I. Introduction

Traditional Classification of Amino Acids in Animal Nutrition

Traditional Classification of Amino Acids (AA)

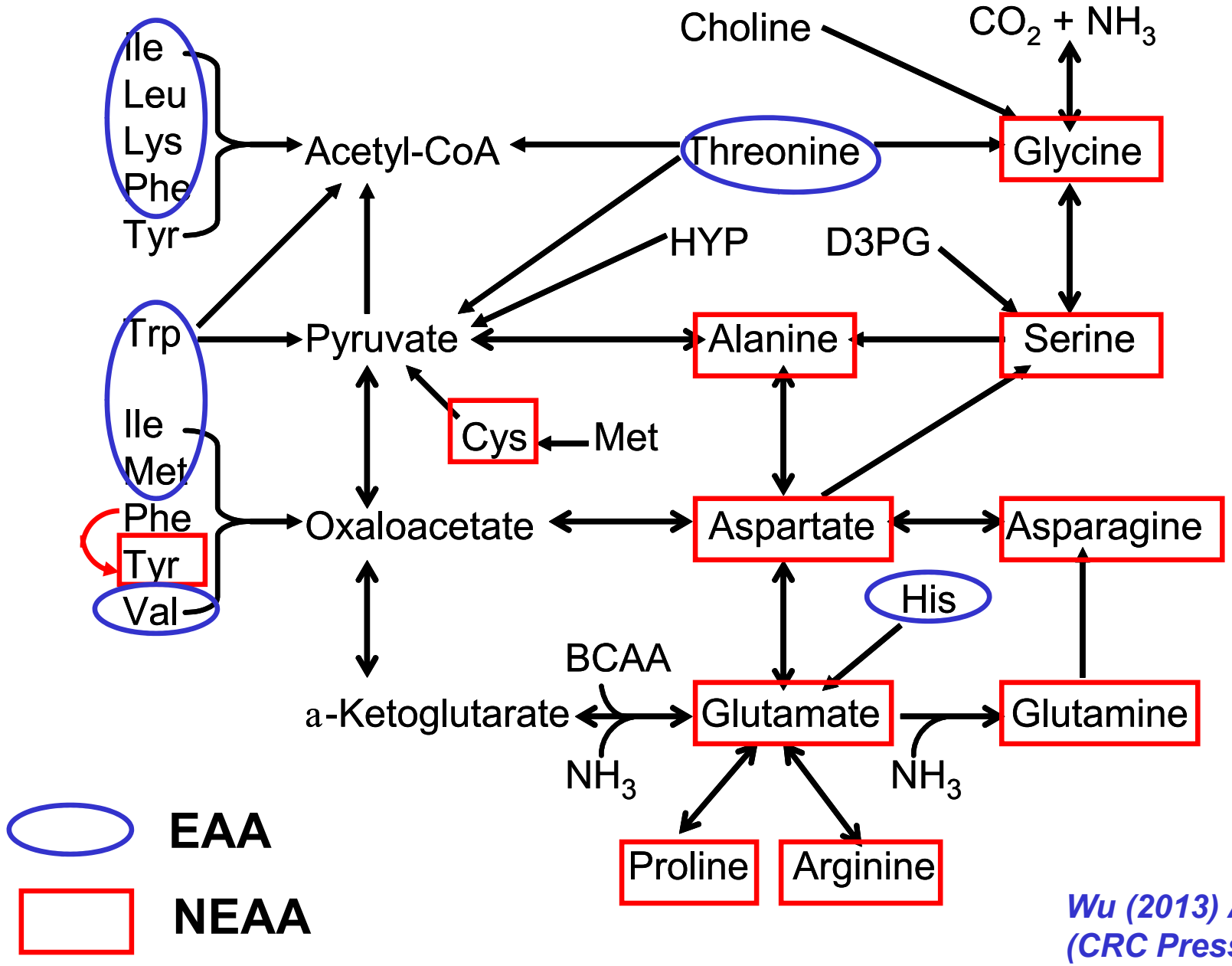
Amino Acids
- Nutritionally essential (EAA)
- Nutritionally nonessential (NEAA)

EAA: AA whose carbon skeletons cannot be made or whose synthesis is insufficient.

NEAA: AA which can be synthesized sufficiently to meet the needs of animals.

Rose WC (1957) Nutr Abstr Rev Ser. 27:631-647

Synthesis of NEAA from EAA in Animals



Wu (2013) Amino Acids (CRC Press)

Functional Amino Acids in Animal Nutrition

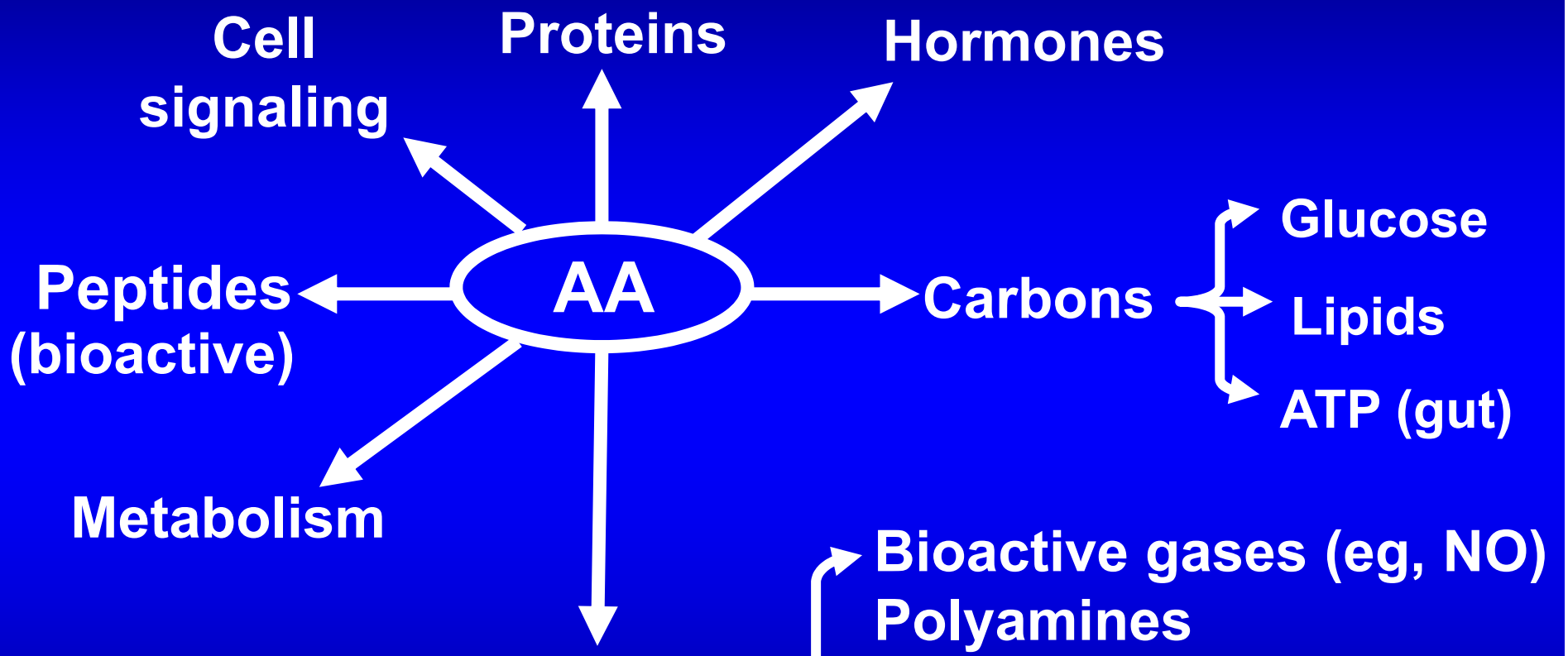
Amino acids that participate in and regulate key metabolic pathways to improve:

--- Health
--- Survival
--- Growth
--- Development
--- Lactation
--- Reproduction

of the organisms.

Wu (2013) Amino Acids 45:407-411

What Amino Acids (AA) Do in Animals?



Wu (2013) Amino Acids 45:407-411

II. Overall Review of regulation of Food Intake by Amino Acids

Importance of Food Intake

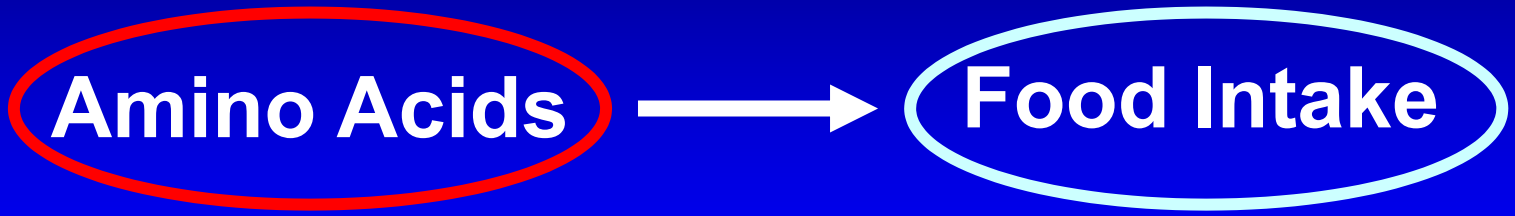
Animals depend on food intake for:

--- Health
--- Survival
--- Growth
--- Development
--- Lactation
--- Reproduction

For the same reason, food intake of animals must be regulated to:

--- Reject
--- Adapt
--- Maintain

Regulation of Food Intake by Amino Acids (AA)



Factors Affecting Effects of AA

- Dietary factors
- Genetic backgrounds
- Physiological states
- Pathological states
- Environmental factors
- Management, Behavior

Wu (2013) Amino Acids: Biochemistry and Nutrition (CRC Press)

Nutritional Factors Affecting the Effects of Amino Acids on Food Intake by Animals

--- Amino acid (AA) content and proportion in diets
--- Dosage and type of supplemental AA
--- Energy content
--- Composition of carbohydrate, lipids, vitamins and minerals
--- Anti-nutritional factors and toxic substances
--- Ingredients used in formulating basal diets
--- Methods of food processing
--- Physical characteristics of diets
(e.g., temp, particle size, color, smell, and taste)
--- Form of the food (liquid, pellet, or powder)
--- Water quality

Genetic Factors Affecting the Effects of Amino Acids on Food Intake by Animals

--- Species (e.g., cattle, fish, horse, humans, pigs, poultry, and sheep)

--- Breeds (leghorn vs. broiler chickens; Meishan vs. offspring of Landrace x Yorkshire gilts and *Duroc x Hampshire* boars)

--- Sex (males and females; boars vs sows)

Physiological and Metabolic Factors Affecting Effects of Amino Acids on Food Intake by Animals

--- Age, Pregnancy, and Lactation

--- Light, Circadian clock, and melatonin

--- Release of hormones and satiety signals from the gut & brain)

--- Concentrations of AA, glucose, fatty acids and their metabolites in plasma and brain

--- Motility of the gastrointestinal tract

Pathological Factors Affecting Effects of Amino Acids on Food Intake by Animals

--- Infection
--- Trauma
--- Neoplasia
--- Diabetes
--- Obesity
--- Cardiovascular disease
--- Fetal growth restriction
--- Nausea
--- Vomiting

Environmental Factors Affecting Effects of Amino Acids on Food Intake by Animals

--- Ambient temperature (e.g., heat stress, cold, local heating)

--- Ambient humidity

--- Air pollution (e.g., $PM_{2.5}$, ammonium sulfate, ammonia, H_2S, CO, and CO_2)

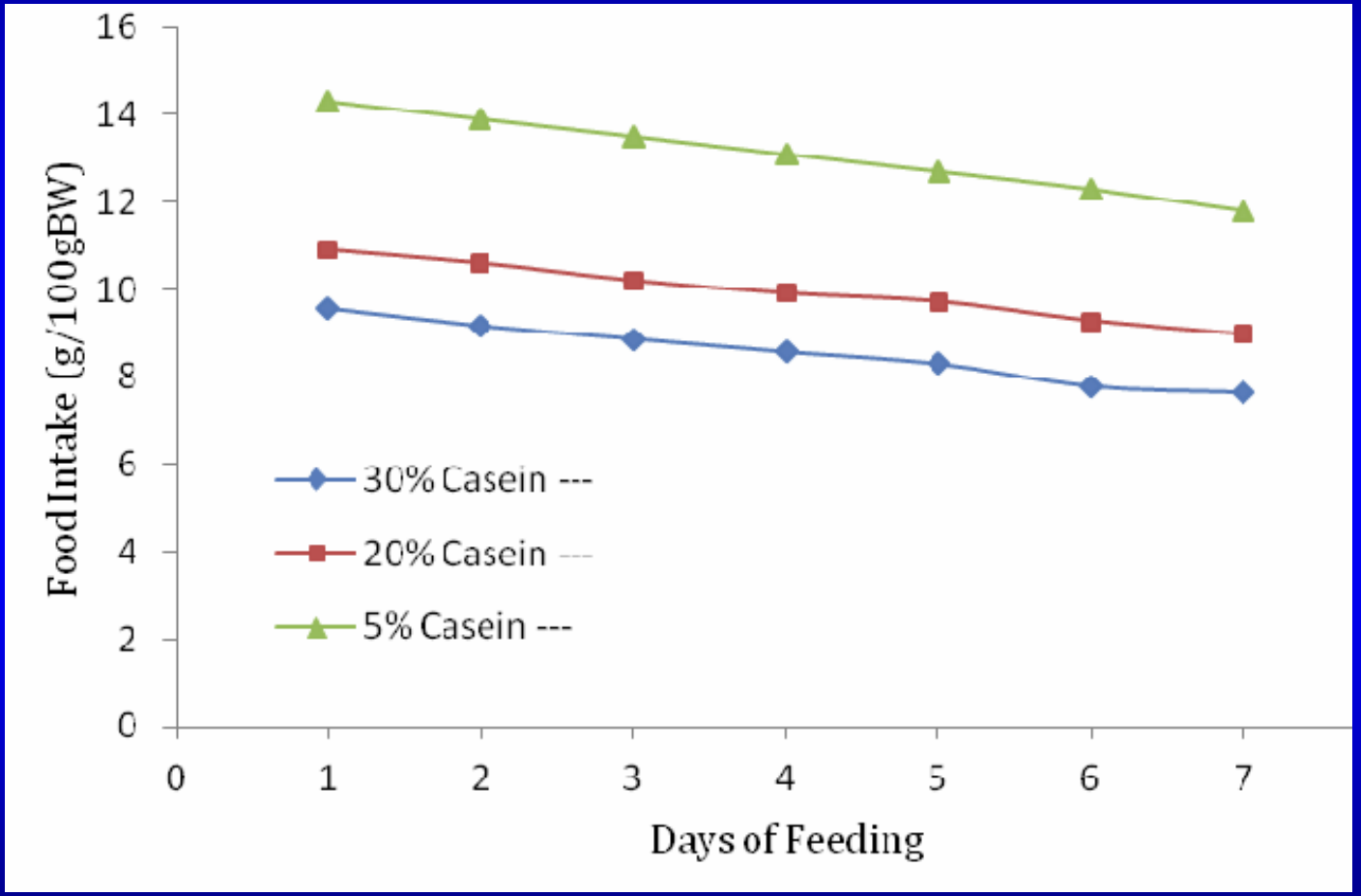
--- Sanitation

Management and Behavioral Factors Affecting Effects of Amino Acids on Food Intake by Animals

--- Frequency of meals
--- Weaning
--- Individual and group hygiene
--- Control of noise
--- Humane treatment of animals
--- Physical activity
--- Dietary habits
--- Social behavior

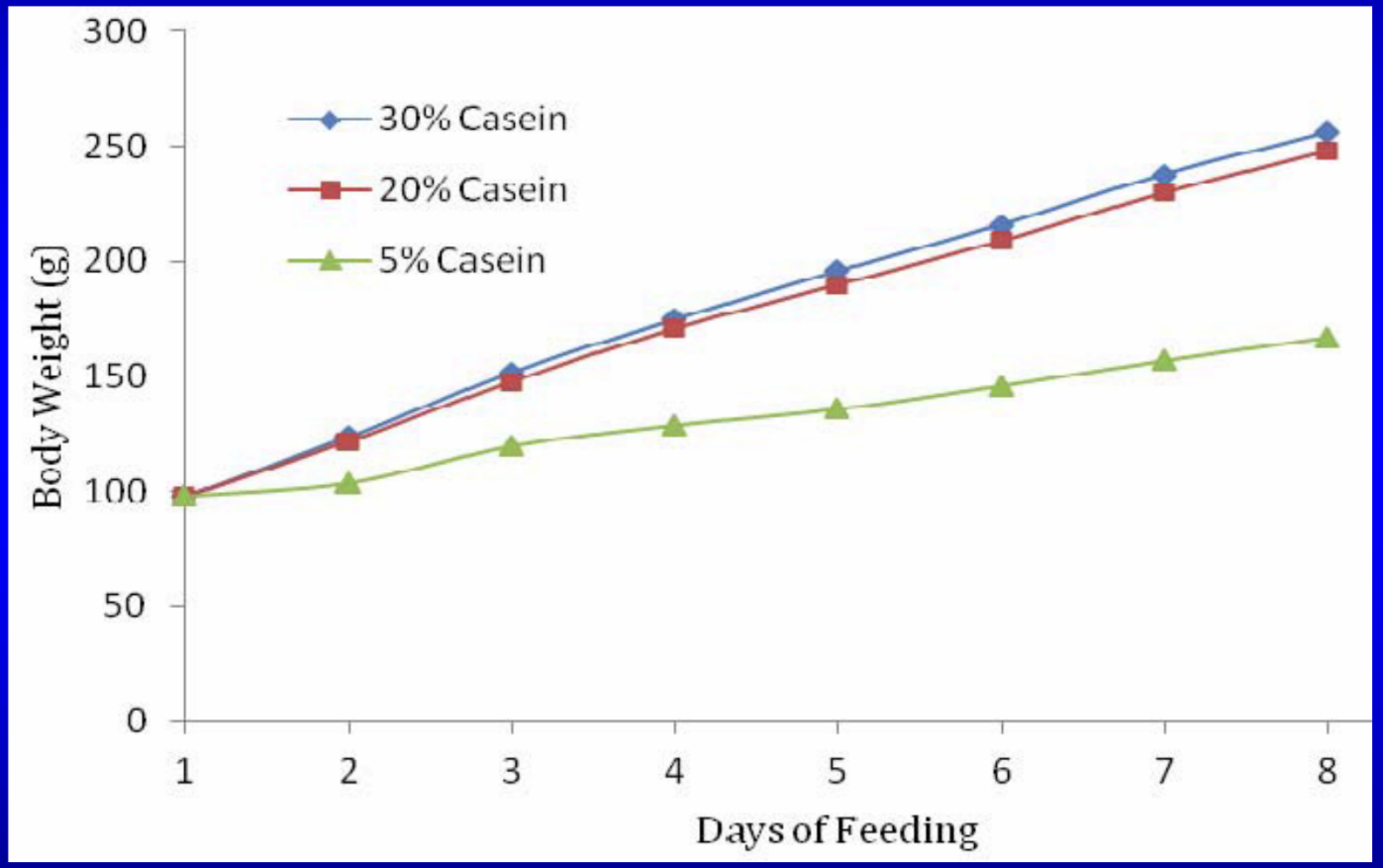
III. Effects of Either Deficiency or Excess of AA in Purified Diets on Food Intake by Animals

Either Deficiency or Excess of All AA in Purified Diets Affects Food Intake by Male Rats



d 0 = 30 days of age (Sprague-Dawley rats)
Values are means ± SEM, n = 10. a-b; P < 0.05.
Wu G (Texas A&M University)

Either Deficiency or Excess of All AA in Purified Diets Affects Growth of Male Rats



d 0 = 30 days of age (Sprague-Dawley rats)
Values are means ± SEM, n = 10. a-b; P < 0.05.
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Animals Rejects A Purified Diet Containing No EAA (Either One EAA or A Group of EAA)

Birds, Pigs, and Rats:

Reject a purified diet containing no EAA.

Rats:

Rejection occurs between 15 and 30 min after starting consumption of the diet.

Rose (1957) Nutr Abstr Rev Ser. 27:631-647
Harper et al (1970) Physiol Rev 50:428-458
Gietzen et al. (2007) Annu Rev Nutr 27:63-78

Repletion of EAA-Devoid Diets

Birds, Pigs, and Rats:

When the basal EAA-free diet is repleted with the missing EAA, animals continue to eat until satiation.

Rats:

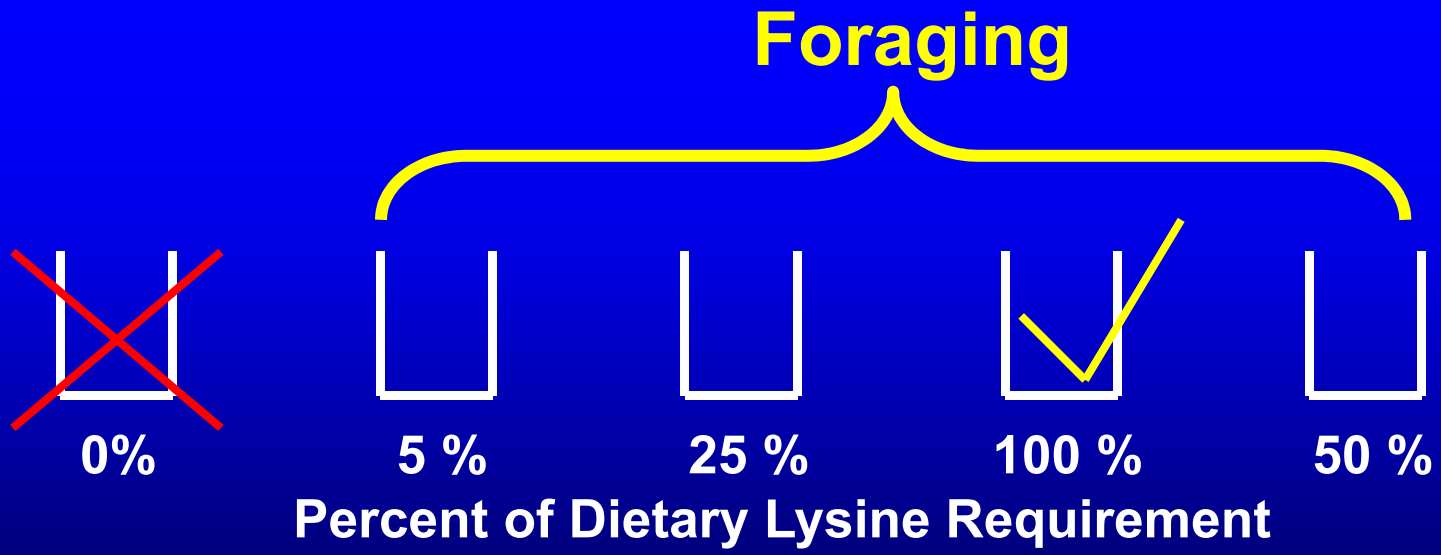
The threshold for sensing EAA in diet: ~100 ppm.

Rose (1957) Nutr Abstr Rev Ser. 27:631-647
Harper et al (1970) Physiol Rev 50:428-458
Gietzen et al. (2007) Annu Rev Nutr 27:63-78

Choices Among EAA-Deficient and Adequate Diets

Birds, Pigs, and Rats:

If choices are given, animals do not consume an EAA-deficient diet, forage diets containing some EAA, and select a diet containing sufficient EAA.



Harper et al (1970) Physiol Rev 50:428-458; Gietzen et al. (2007) Annu Rev Nutr 27:63-78

Animals Eat Less When Fed A Purified Diet Containing Excessive EAA (Either One or A Group)

Birds, pigs & rats eat 25-60% less if a diet contains:

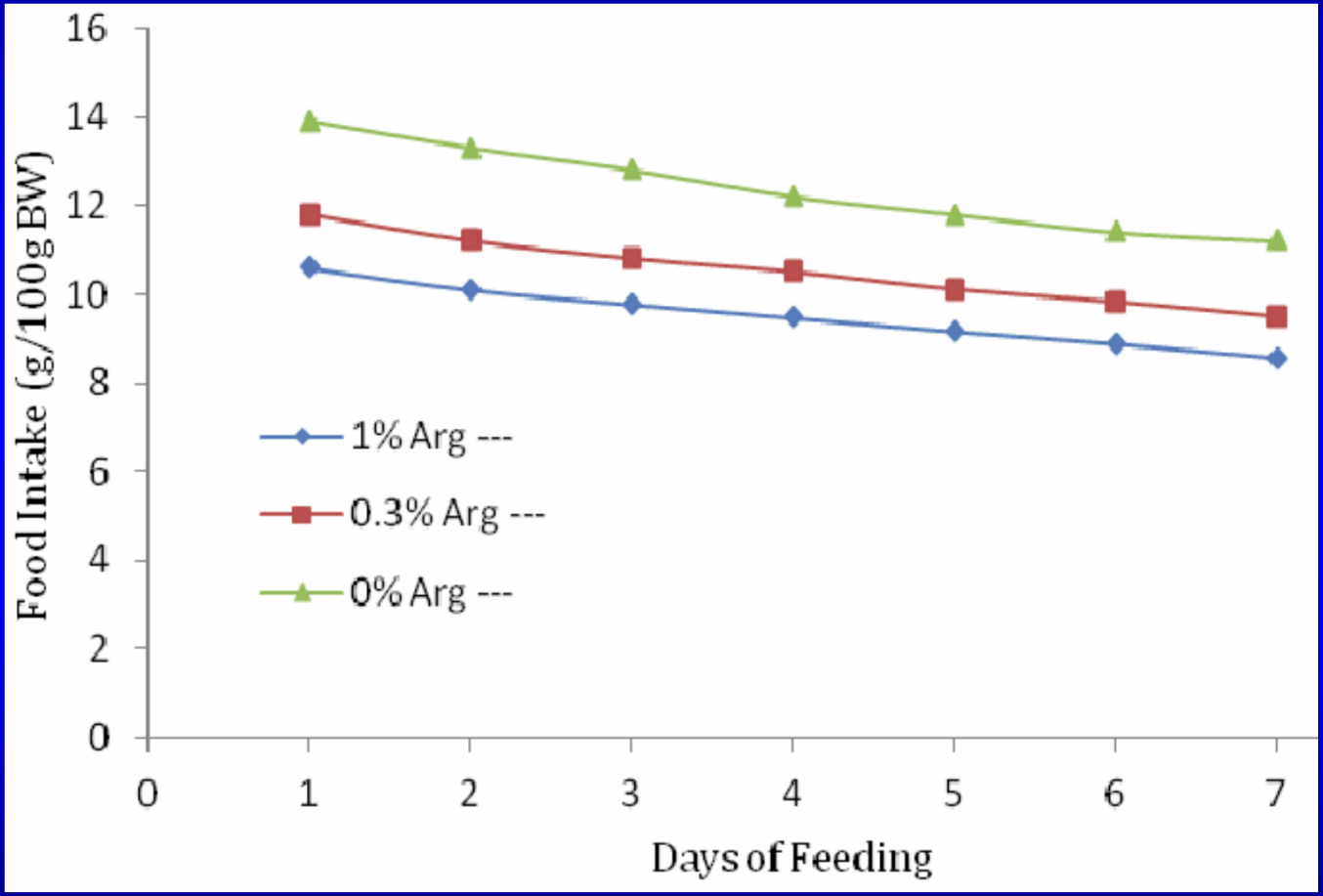
2% Trytophan

3% Histidine, Methionine, Phenylalanine, Threonine or Lysine

4% Leucine, Isoleucine, or Valine

Harper et al (1970) Physiol Rev 50:428-458
Koehnle & Gietzen et al. (2005) Nutritional Neuroscience. Pp. 147-161.

Either Deficiency or Excess of A Synthesizable AA in Purified Diets Affects Feed Intake (Arginine for Rats)



d 0 = 30 days of age (Sprague-Dawley rats)
Values are means ± SEM, n = 10. a-b; P < 0.05.
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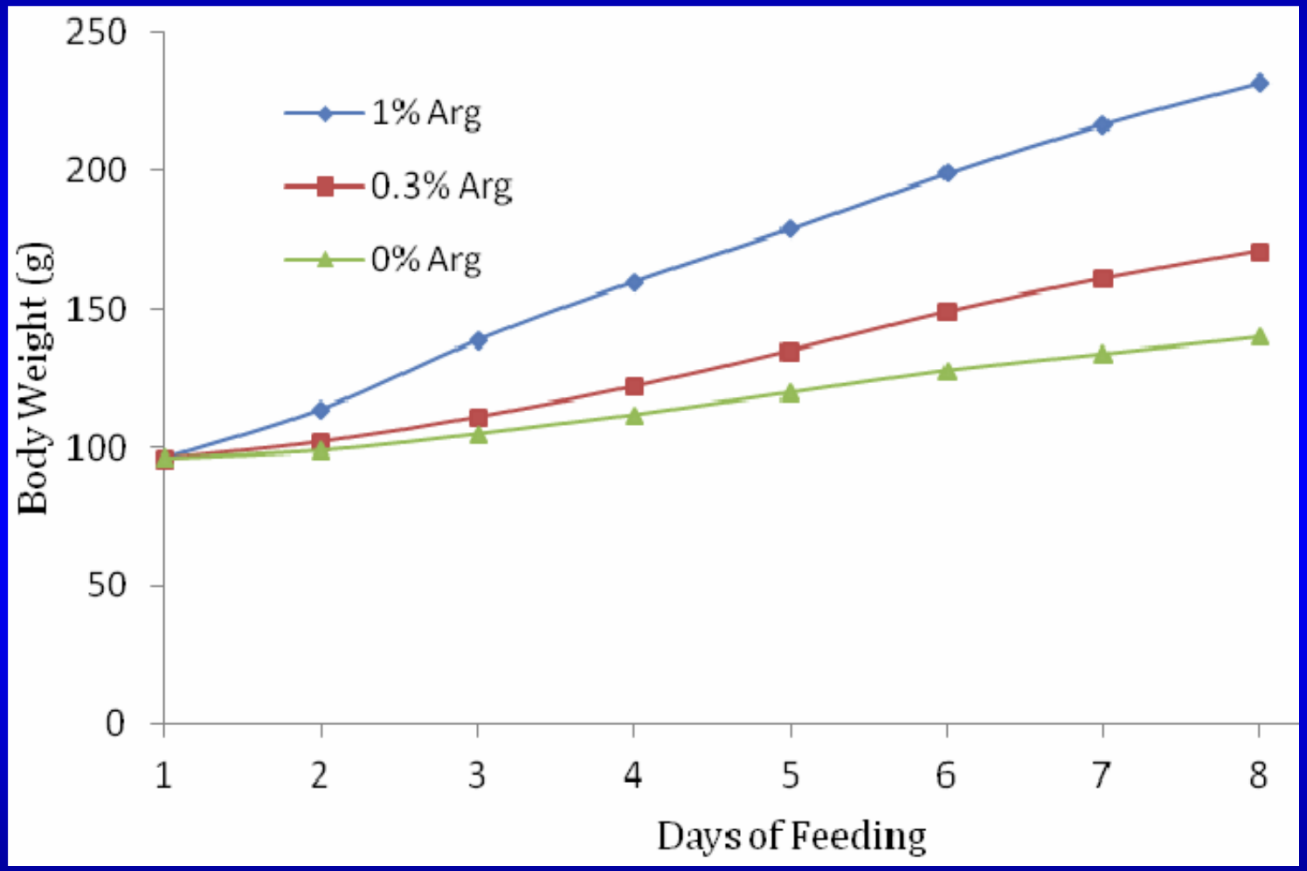
Either Deficiency or Excess of A Synthesizable AA in Purified Diets Affects Growth (Arginine for Rats)



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Values are means ± SEM, n = 10. a-b; P < 0.05.
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Either Deficiency or Excess of A Synthesizable AA in Purified Diets Affects Feed Intake (Glycine for Pigs)

Weeks	Supplemental Glycine in Diet (%)				Pooled SEM
	0.0	0.5	1.0	2.0	
d 0-7	33.1^{c}	35.6^{b}	36.4^{b}	38.8^{a}	0.79
d 7-14	32.6^{c}	34.8^{b}	36.0^{b}	38.1^{a}	0.66

n = 8. Pigs were fed a casein-based diet between 14 and 28 days of age.
d 0 = 14 days of age.
a-b: $P < 0.05$.

Wang et al. (2014)

IV. Effects of Either Deficiency or Excess of AA in Complex Diets on Food Intake by Animals

IV. Effects of Either Deficiency or Excess of AA in Complex Diets on Food Intake by Animals

Animals eat Less when fed a Severely EAA-deficient complex diets (either one or a group of EAA).

However, responses to mild EAA-deficient diets depend on individual amino acids:

- ↑ Feed intake: e.g., Lysine, Methionine, and Threonine
- ↓ Feed intake: e.g., Tryptophan

Le Floc'h and Sève (2007) Livest Sci 112:23-32
Edmonds and Baker (1987) J Anim Sci 64:1664-71

Effects of Dietary Protein and Methionine (EAA) Levels on Feed Intake by Lactating Cows

Variable	Crude Protein		Rumen-Protected Met		SEM
	15.8%	17.1%	0 g/d	9 g/d	
DM Intake (kg/day)	24.4	25.5*	24.6	25.3*	0.37
Milk yield (kg/day)	40.0	41.7*	40.0	41.4†	0.72

Holstein cows were fed corn silage-based experimental diets for 4 weeks.
* P < 0.05; † P = 0.10.

Broderick et al. J dairy Sci 92:2719-28.

Animals Eat Less When Fed Complex Diets Containing Excessive EAA (Either One or A Group)

Birds, pigs & rats eat 10-55% less if a diet contains:

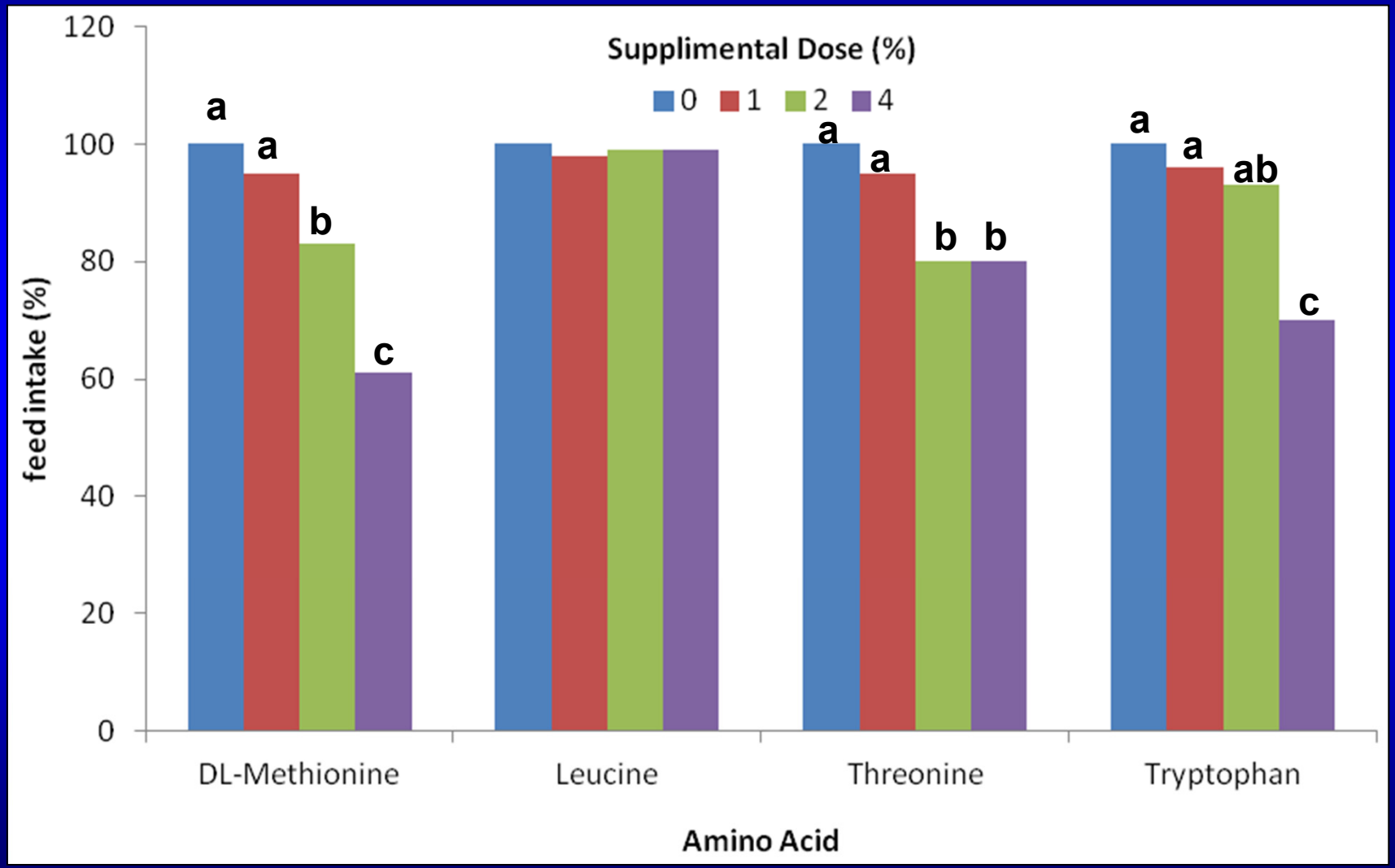
4% Trytophan

4% Histidine, Methionine, Phenylalanine, Threonine or Lysine

6% Leucine, Isoleucine, or Valine

Edmonds and Baker (1987) J Anim Sci 64: 1664-71; 65:699-705.

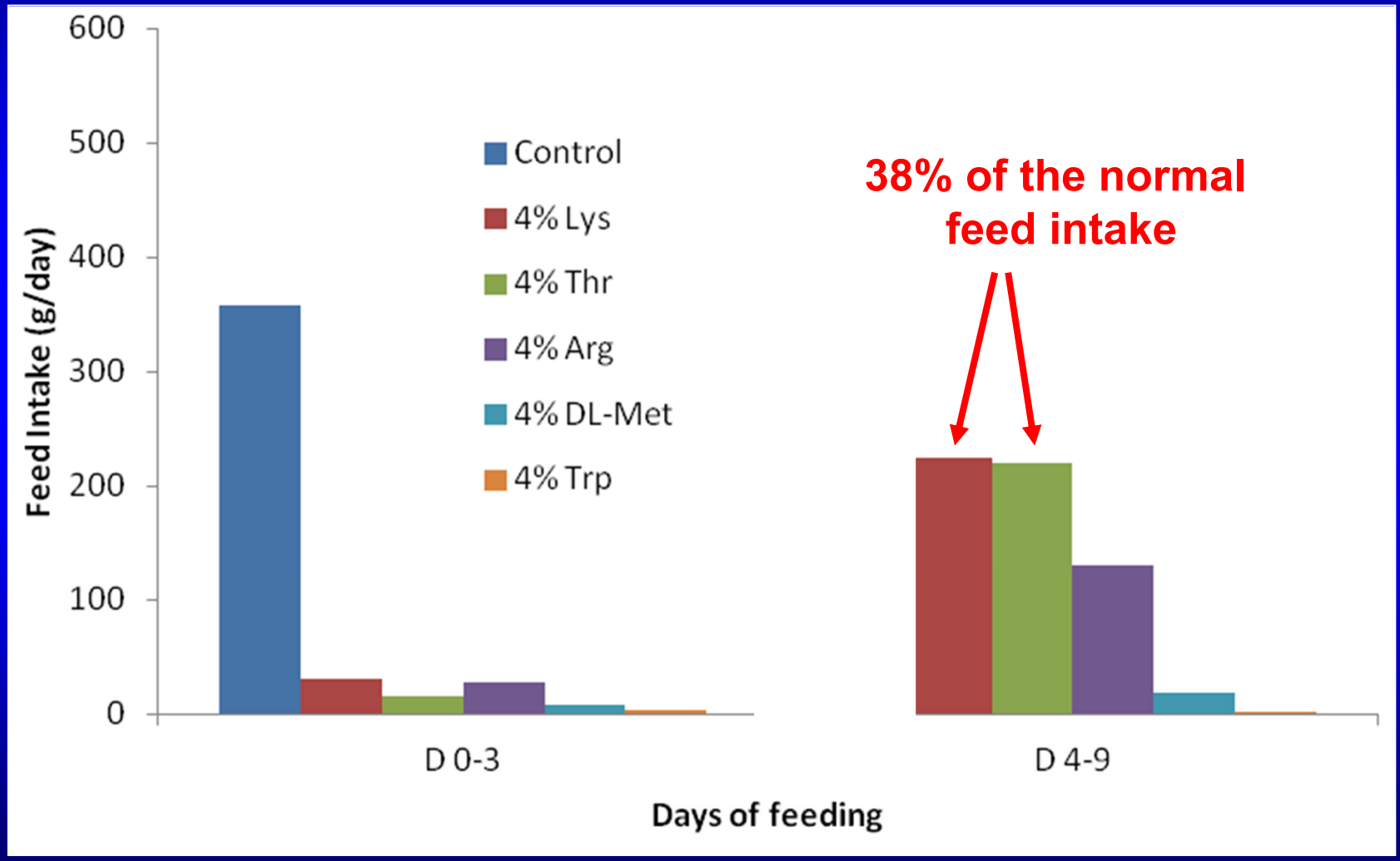
Weanling Pigs (8 kg) Eat Less When Fed Corn- and Soybean Meal-Based Diets (Complex Diets) Supplemented with An Excessive EAA



Edmonds and Baker (1987) J Anim Sci 64: 1664-71.

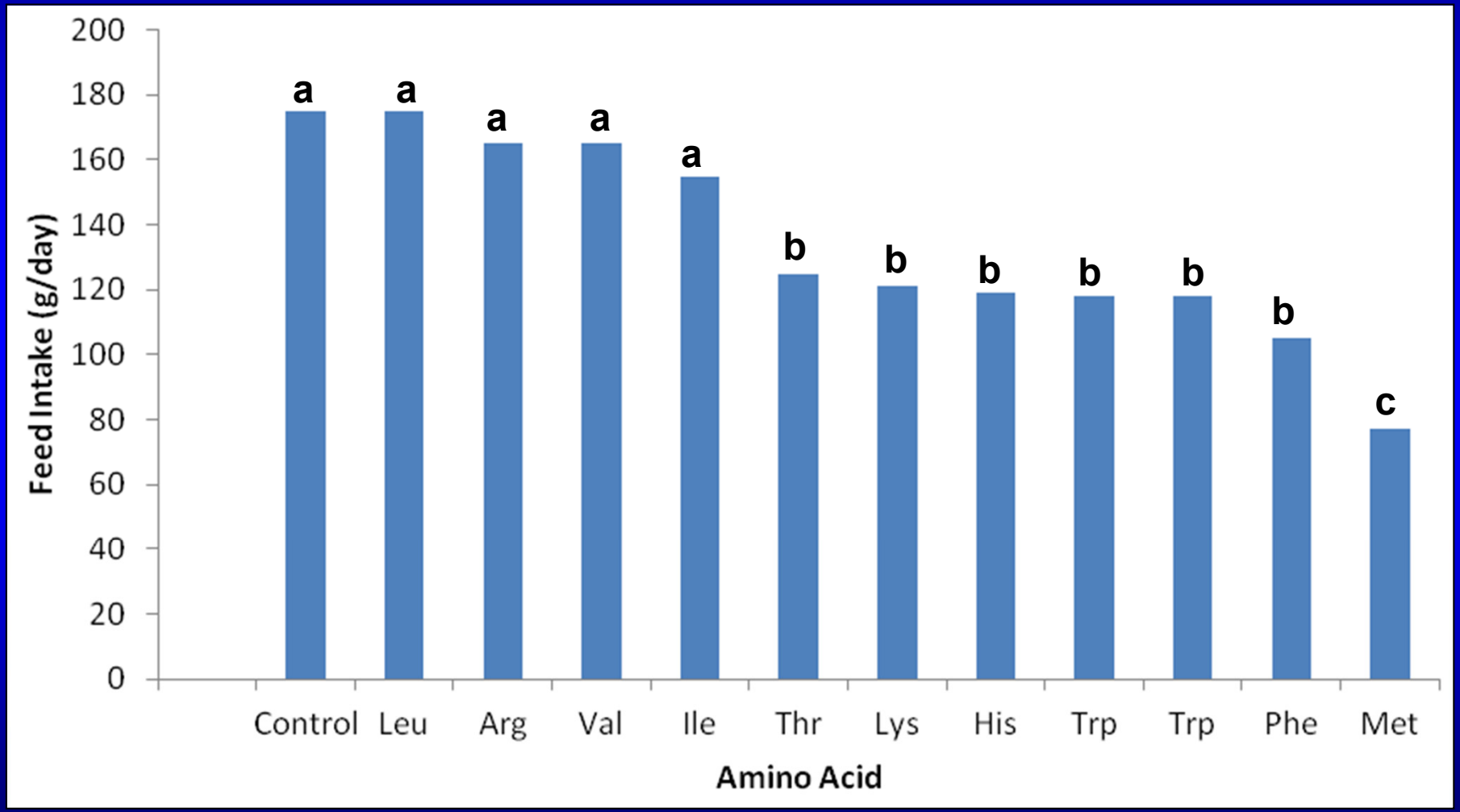
a-c; P < 0.05

Self-selection of Corn- and Soybean Meal-Based Diets (Complex Diets) by Young Pigs Supplemented with or without An Excessive EAA



Edmonds and Baker (1987) J Anim Sci 65: 179-185.

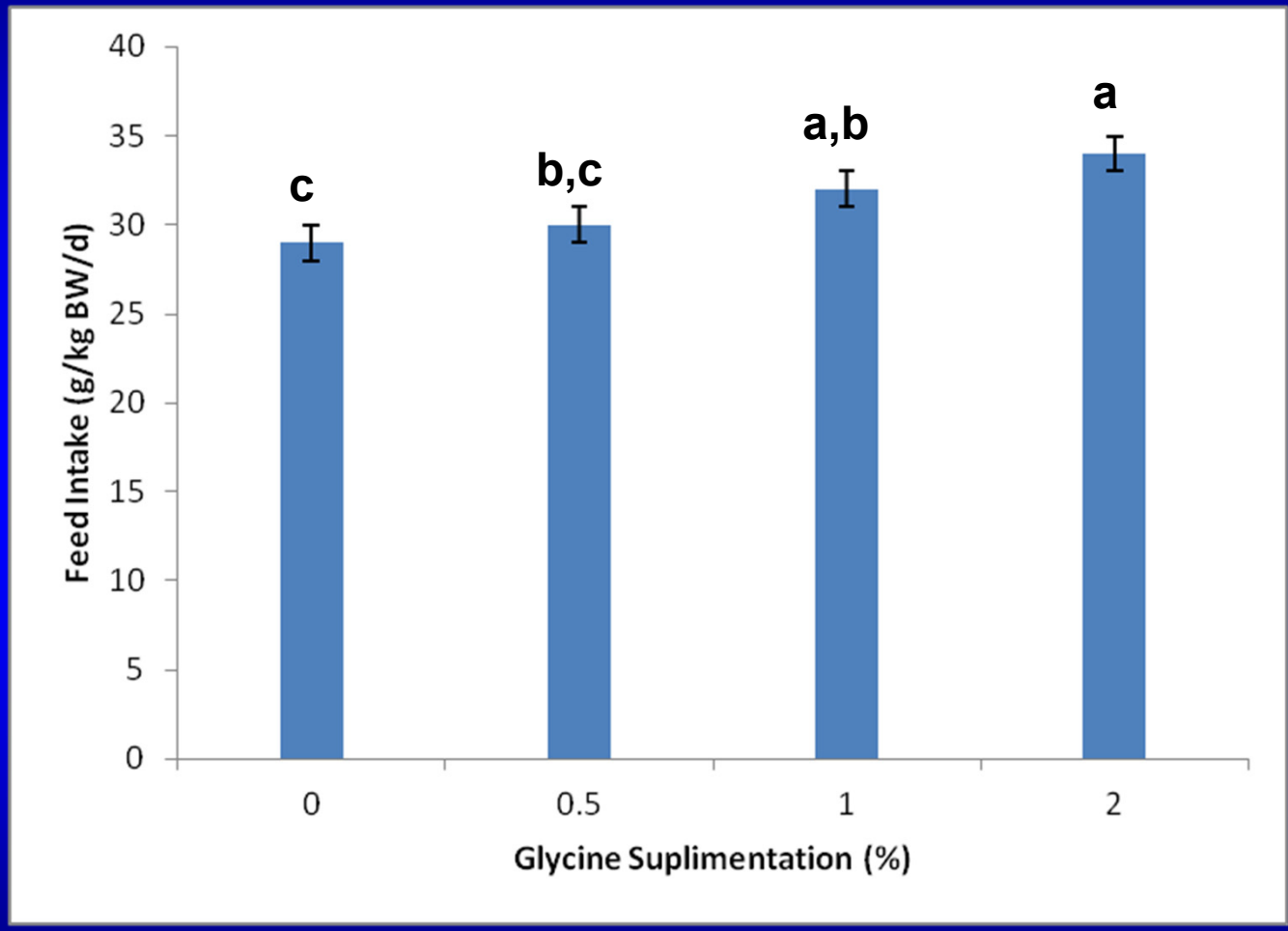
Young Chicks Eat Less When Fed Corn- and Soybean Meal-Based Diets (Complex Diets) Supplemented with An Excessive EAA



Edmonds and Baker (1987) J Anim Sci 65: 699-705.

a-c; P < 0.05

Either Deficiency or Excess of A Synthesizable AA in A Complex Diet Affects Food Intake (Glycine for Pigs)



Means ± SEM, n = 8. Pigs were fed a corn- and soybean meal-based diet between d 28 and 42. d 0 = 28 days of age (weaning). .

Wang et al. (2014)

Effects of Dietary Supplementation with Glutamine or Glutamate on Feed Intake by Weanling Pigs

AA	Dietary Supplementation (%)				Pooled SEM
	0.0	0.5	1.0	2.0	
Glutamine	348[a]	353[a]	342[a]	287[b]	19
Glutamate	352	356	361	358	22

n = 12. Values (g/d) are for the 2nd week postweaning. Pigs were weaned at 21 days of age to a corn- and soybean meal-based diet containing 21%. a-b: $P < 0.05$.

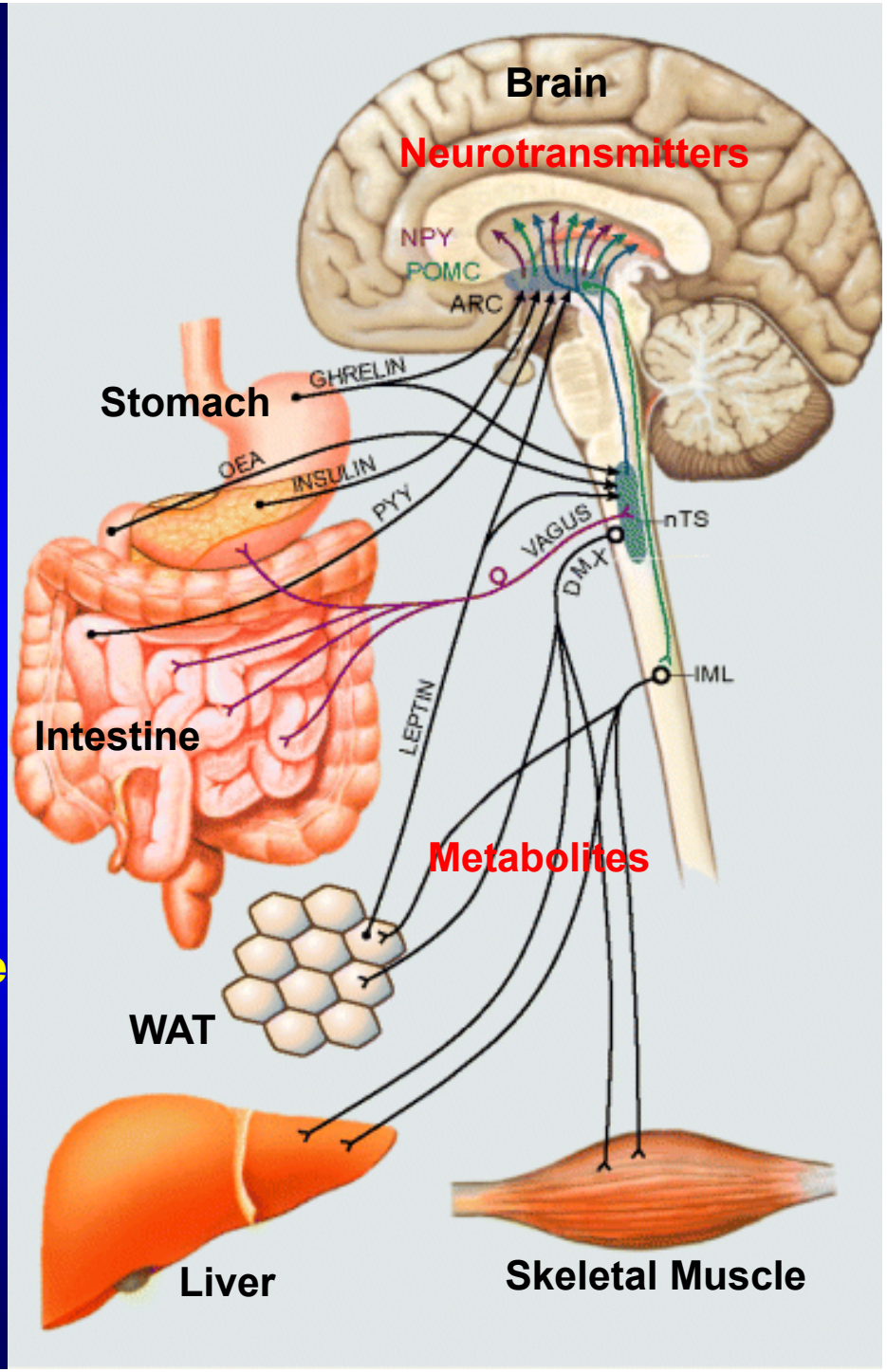
Wu G. Texas A&M University

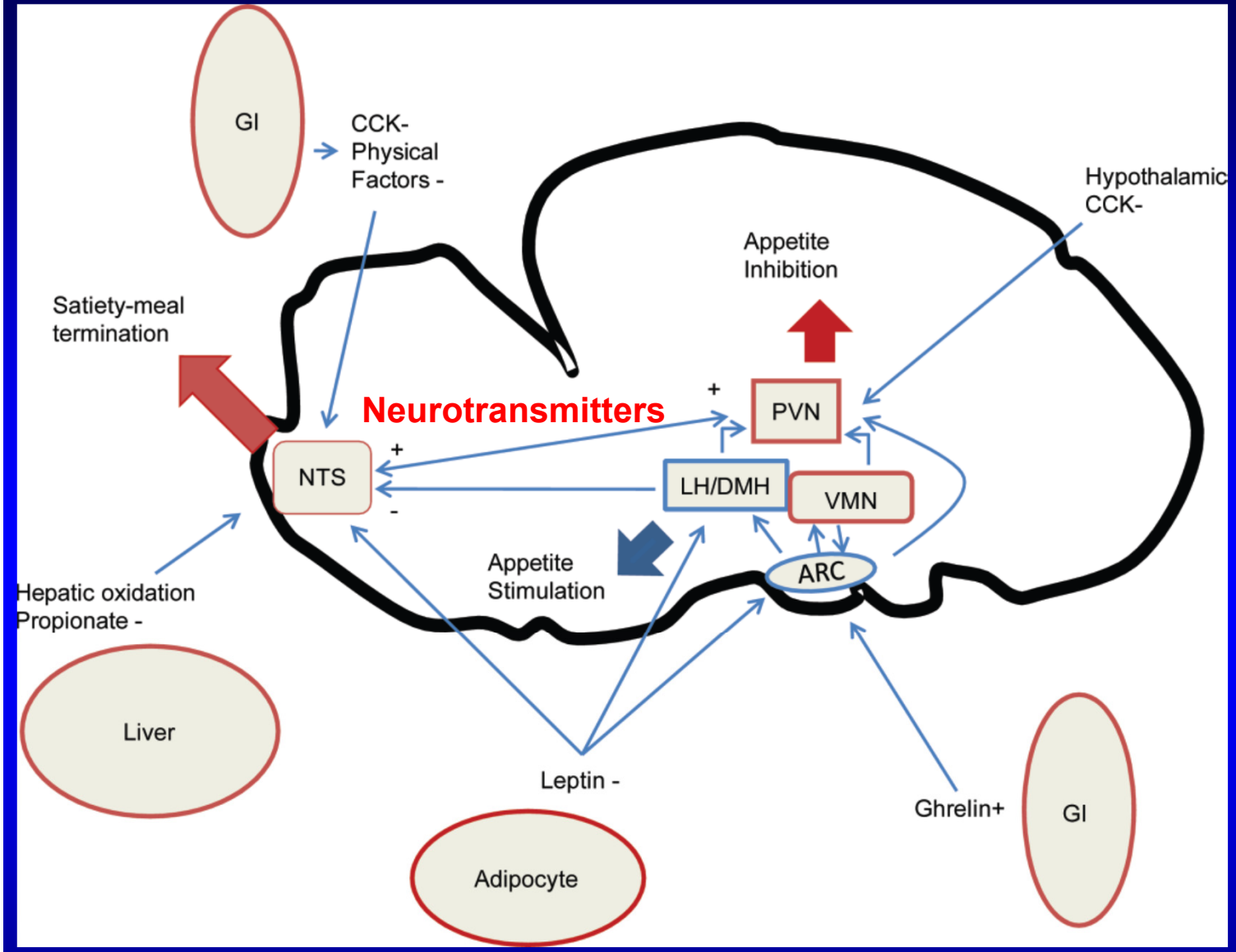
IV. Mechanisms Responsible for Effects of Dietary Amino Acids on Food Intake by Animals

Brain Regulation of Food Intake: Molecules and Networks *Broberger C (2005) J Int Med 258:301-327*

The brain integrates signals from the stomach, intestine, liver and blood to regulate food intake.

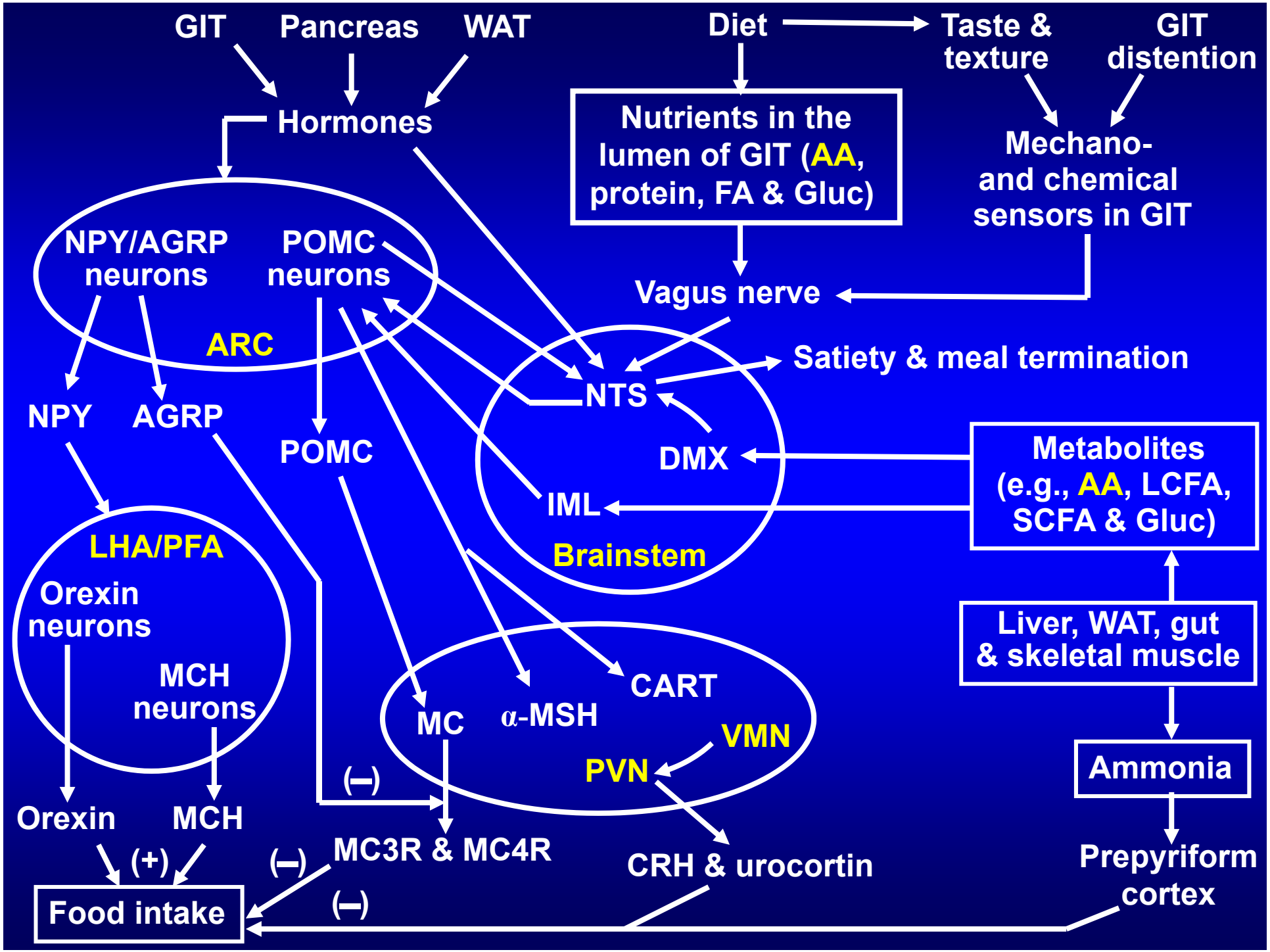
ARC: Arcuate nucleus (hypothalamus)
DMX: Dorsal motor nucleus of vagus nerve
IML: Intermediolateral cell column
nTS: Nucleus tractus solitarii (brainstem)
NPY: Neuropeptide Y
OEA: Oleoylethanolamide (fatty acid)
POMC: Pro-opiomelanocortin
PYY: Peptide YY (36-AA peptide)





Sartin JL et al. (2011) J Anim Sci 89:1991-2003

ARC, Arcuate; CCK, Cholecystokinin; DMH, Dorsomedial hypothalamus; LH, Lateral hypothalamus; PVN, Paraventricular nucleus; NTS, Nucleus tractus solitarius; VMN, ventromedial nucleus


GIT
Pancreas
WAT
Hormones
Diet
Taste & texture
GIT distention
Nutrients in the lumen of GIT (AA, protein, FA & Gluc)
Mechano- and chemical sensors in GIT
Vagus nerve
NPY/AGRP neurons
POMC neurons
ARC
NTS
Satiety & meal termination
NPY
AGRP
POMC
DMX
IML
Brainstem
Metabolites (e.g., AA, LCFA, SCFA & Gluc)
LHA/PFA
Orexin neurons
MCH neurons
Liver, WAT, gut & skeletal muscle
CART
MC
α-MSH
VMN
PVN
Ammonia
(–)
Orexin
MCH
(+)
(–)
MC3R & MC4R
CRH & urocortin
Prepyriform cortex
(–)
Food intake

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Texas A&M University

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