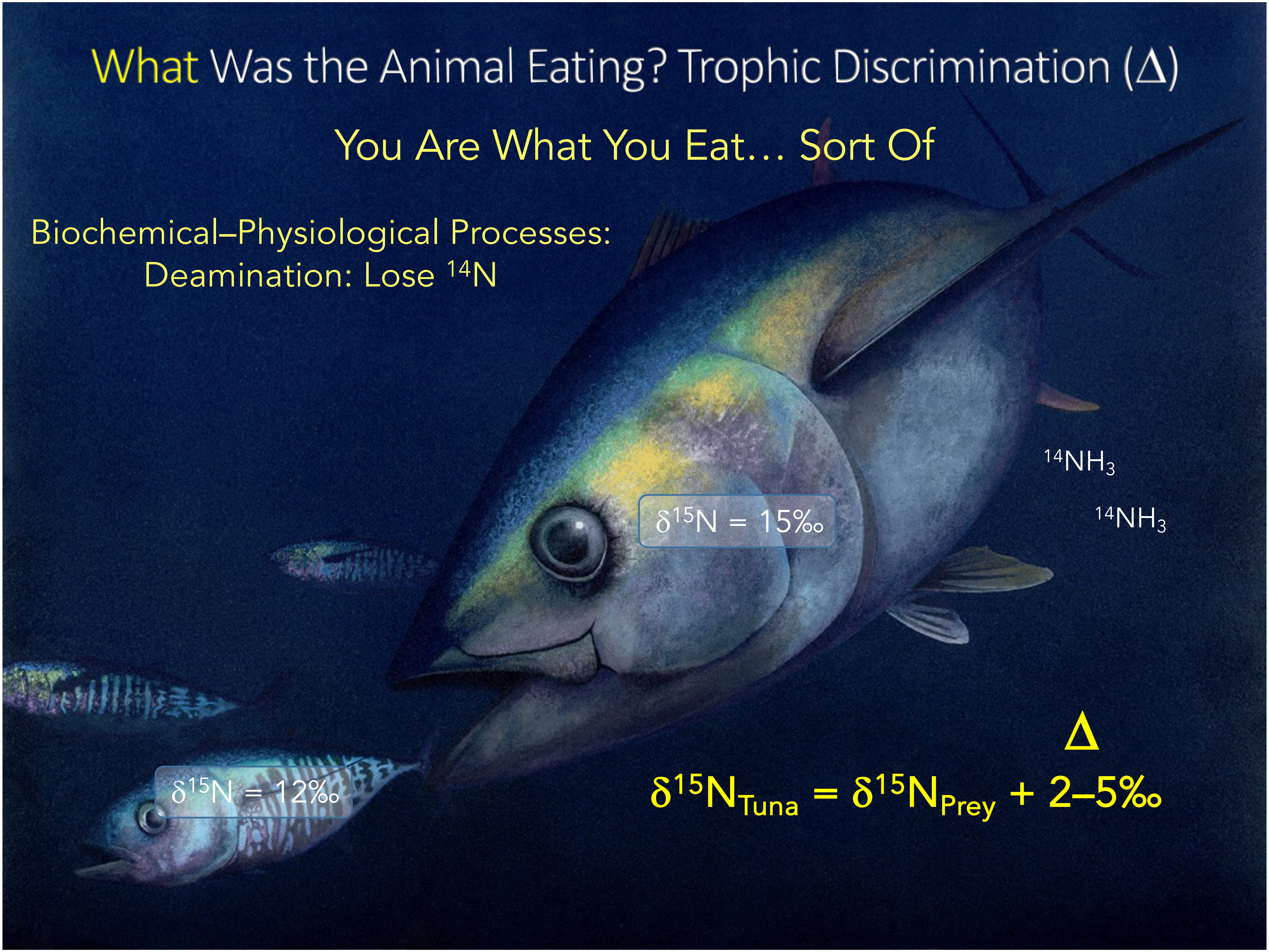
Consumer $\delta^{15}N$

Nitrogen

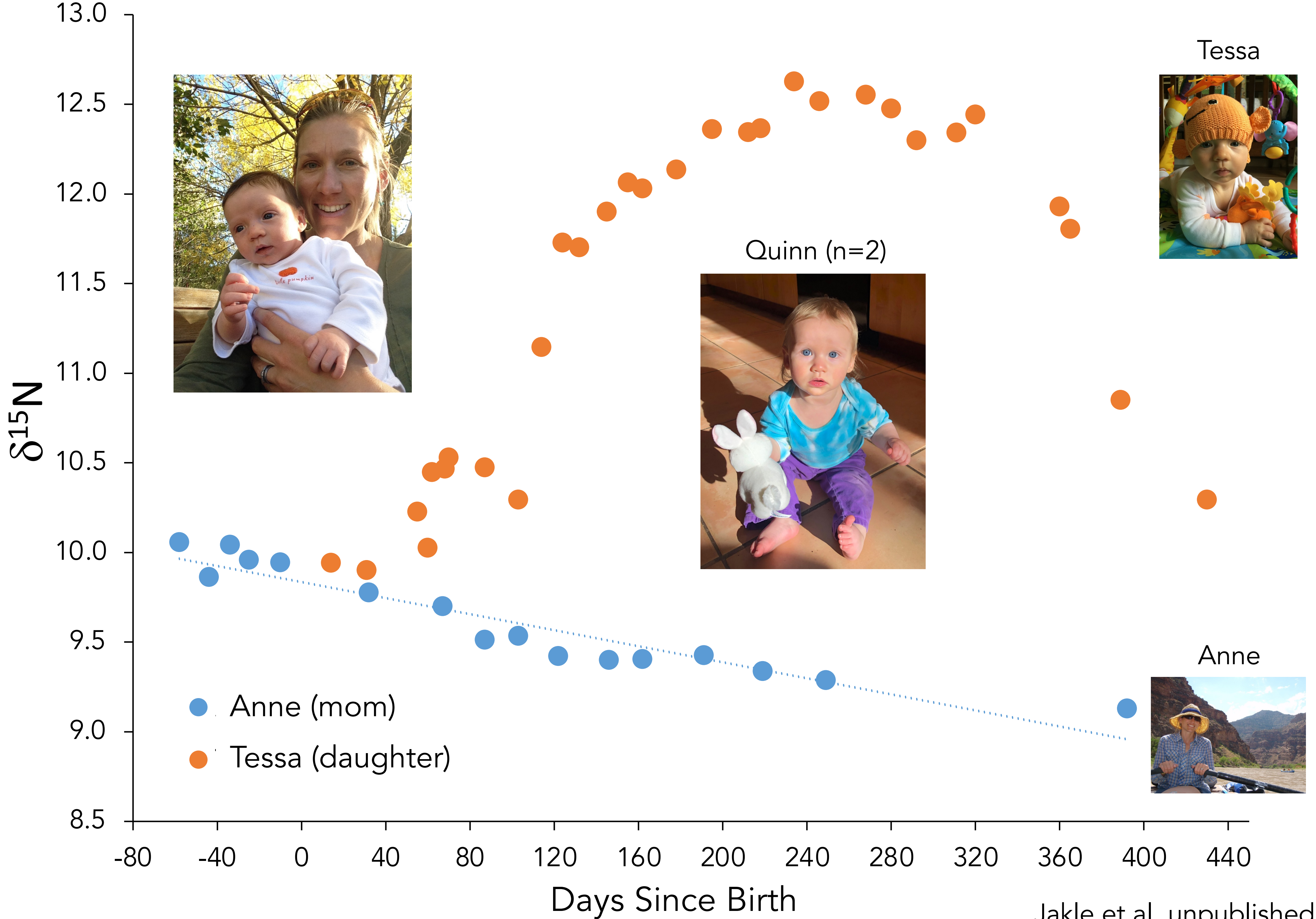
Main groups — Transition metals — Main groups

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 8B	10	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 **H** 1.00794																	2 **He** 4.00260
3 **Li** 6.941	4 **Be** 9.01218											5 **B** 10.81	6 **C** 12.011	7 **N** 14.0067	8 **O** 15.9994	9 **F** 18.998403	10 **Ne** 20.1797
11 **Na** 22.98977	12 **Mg** 24.305											13 **Al** 26.98154	14 **Si** 28.0855	15 **P** 30.97376	16 **S** 32.066	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.0983	20 **Ca** 40.078	21 **Sc** 44.9559	22 **Ti** 47.88	23 **V** 50.9415	24 **Cr** 51.996	25 **Mn** 54.9380	26 **Fe** 55.847	27 **Co** 58.9332	28 **Ni** 58.69	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.61	33 **As** 74.9216	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
37 **Rb** 85.4678	38 **Sr** 87.62	39 **Y** 88.9059	40 **Zr** 91.224	41 **Nb** 92.9064	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.9055	46 **Pd** 106.42	47 **Ag** 107.8682	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.710	51 **Sb** 121.757	52 **Te** 127.60	53 **I** 126.9045	54 **Xe** 131.29
55 **Cs** 132.9054	56 **Ba** 137.33	57 ***La** 138.9055	72 **Hf** 178.49	73 **Ta** 180.9479	74 **W** 183.85	75 **Re** 186.207	76 **Os** 190.2	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.9665	80 **Hg** 200.59	81 **Tl** 204.383	82 **Pb** 207.2	83 **Bi** 208.9804	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.0254	89 **†Ac** 227.0278	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (269)	109 **Mt** (268)	110 (271)	111 (272)	112 (277)		114 (289)		116 (289)		118 (293)

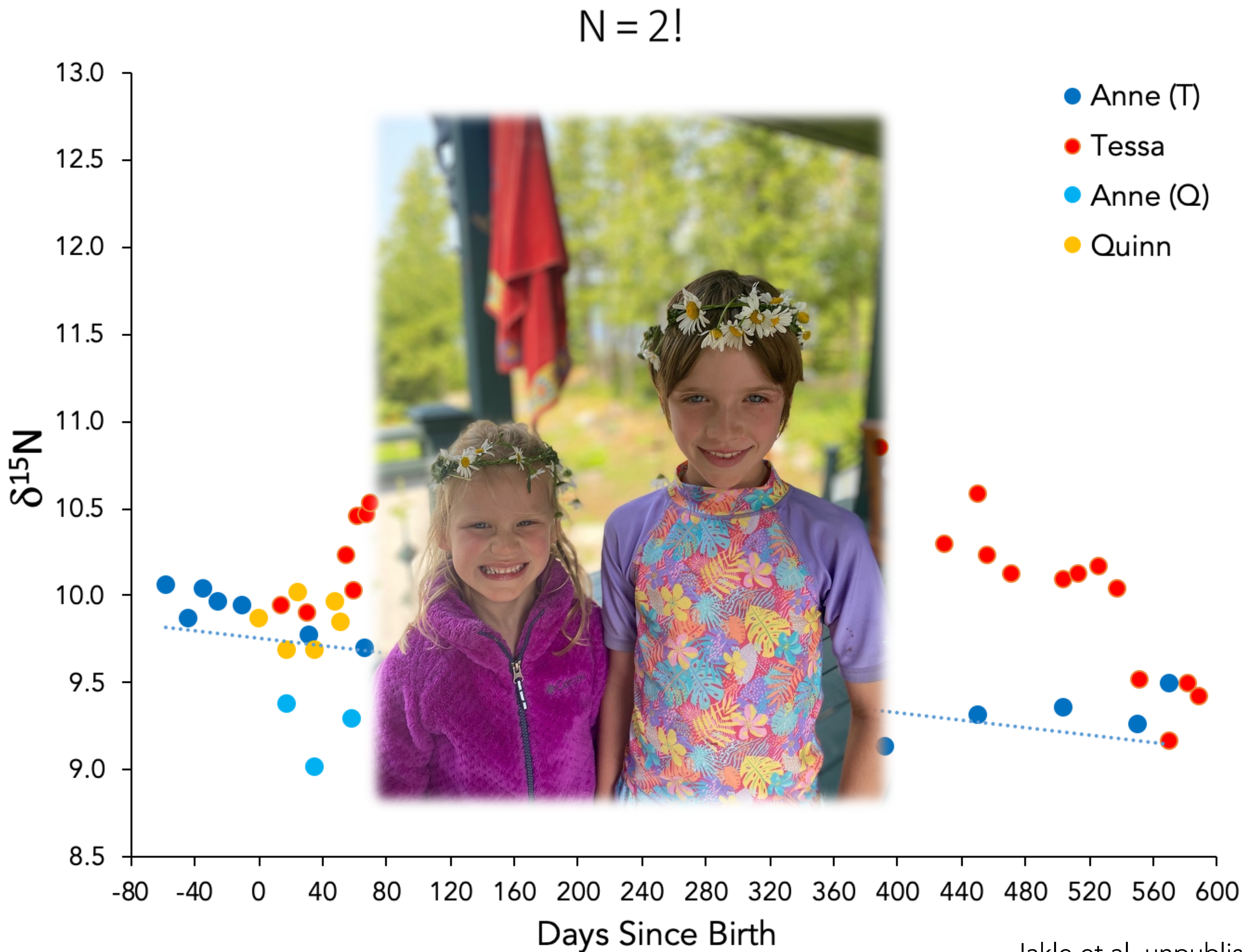
*Lanthanide series	58 **Ce** 140.12	59 **Pr** 140.9077	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.9254	66 **Dy** 162.50	67 **Ho** 164.9304	68 **Er** 167.26	69 **Tm** 168.9342	70 **Yb** 173.04	71 **Lu** 174.967
†Actinide series	90 **Th** 232.0381	91 **Pa** 231.0359	92 **U** 238.0289	93 **Np** 237.048	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)


What Was the Animal Eating? Trophic Discrimination (Δ)
You Are What You Eat… Sort Of
Biochemical–Physiological Processes:
Deamination: Lose ^{14}N
$^{14}NH_3$
$^{14}NH_3$
$\delta^{15}N = 15‰$
$\delta^{15}N = 12‰$
Δ
$\delta^{15}N_{Tuna} = \delta^{15}N_{Prey} + 2–5‰$

δ¹⁵N: Trophic Level

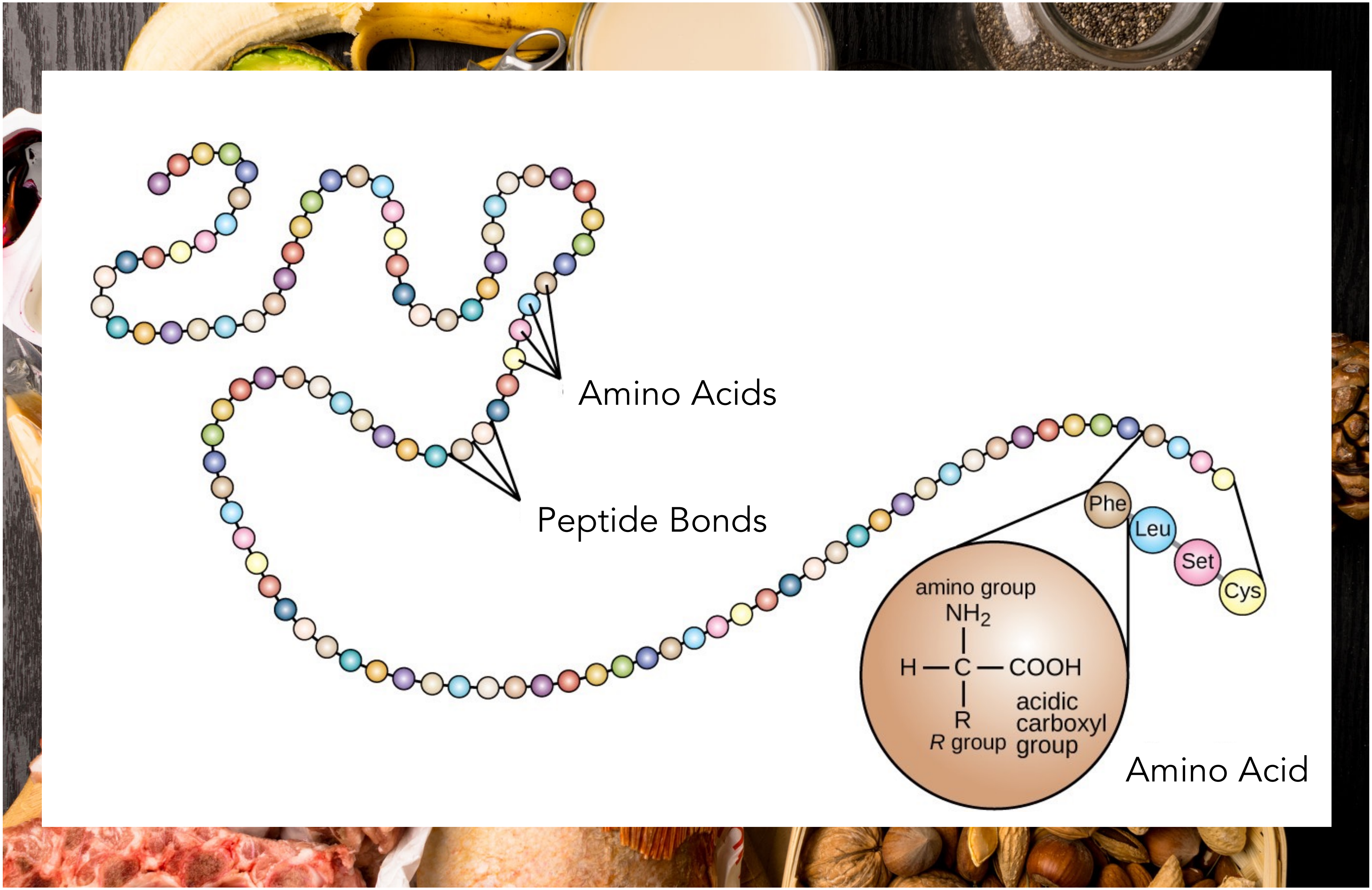


Jakle et al. unpublished

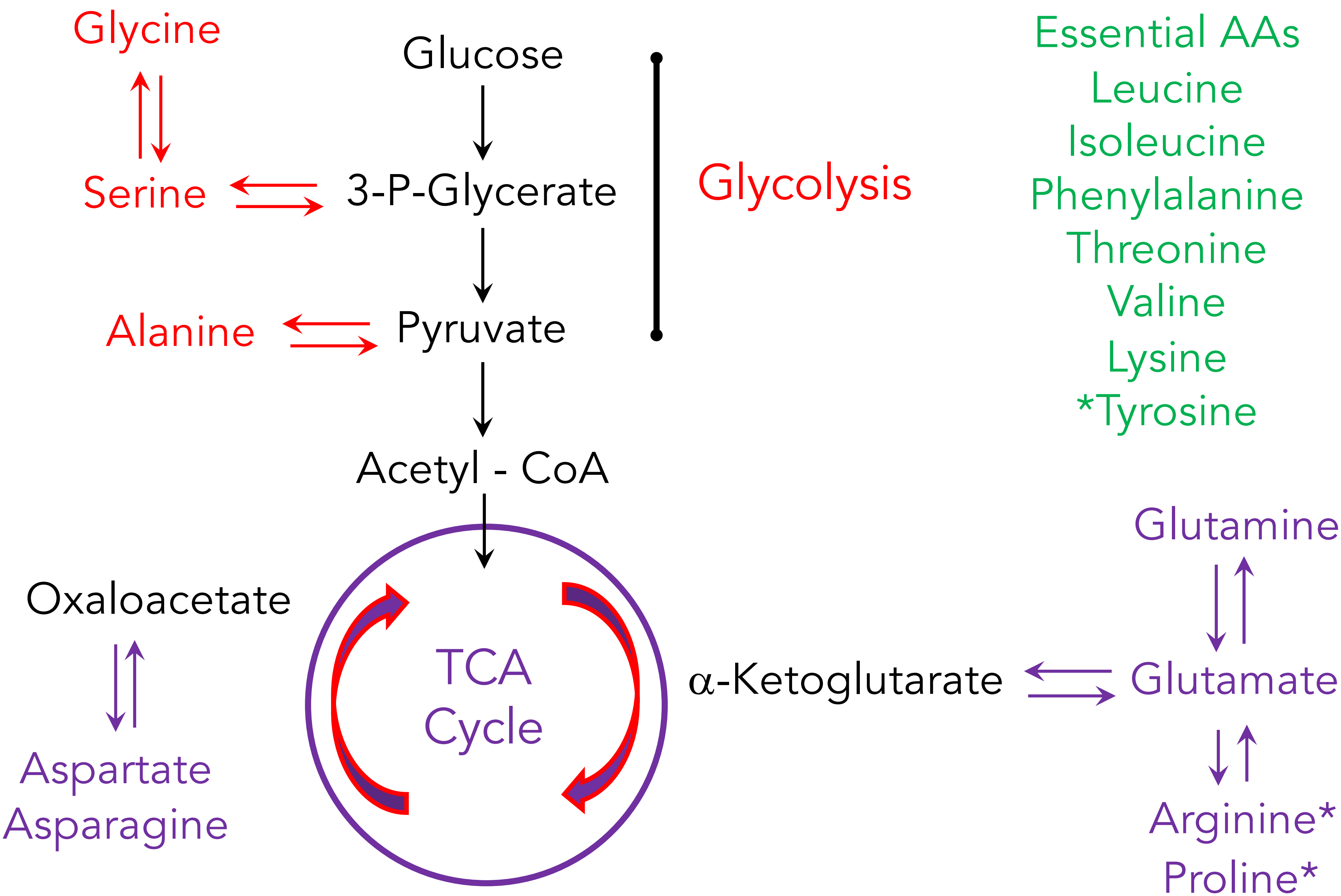


Jakle et al. unpublished

Sources of Nitrogen for Animals?

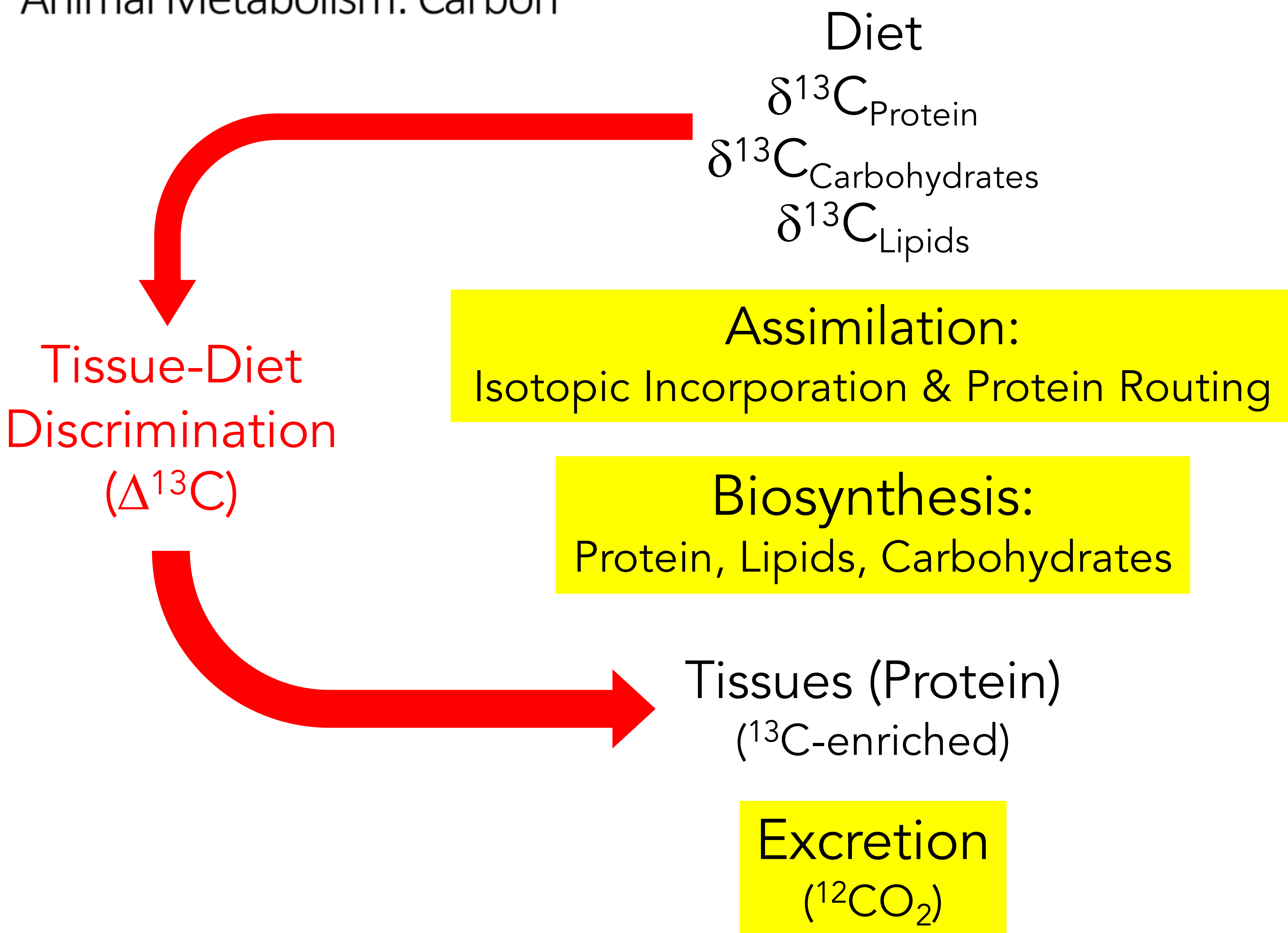


(Major) Amino Acid Metabolism

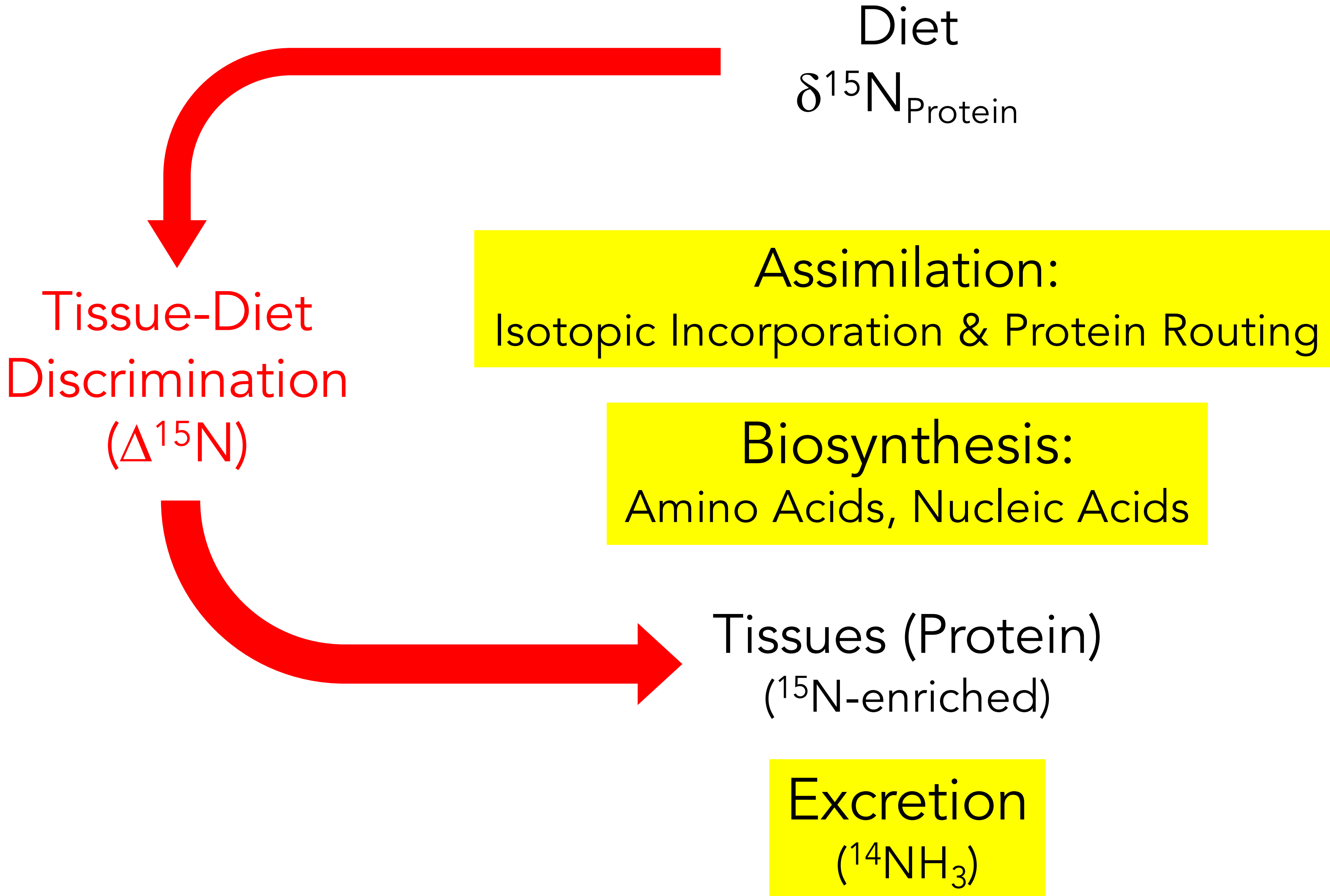


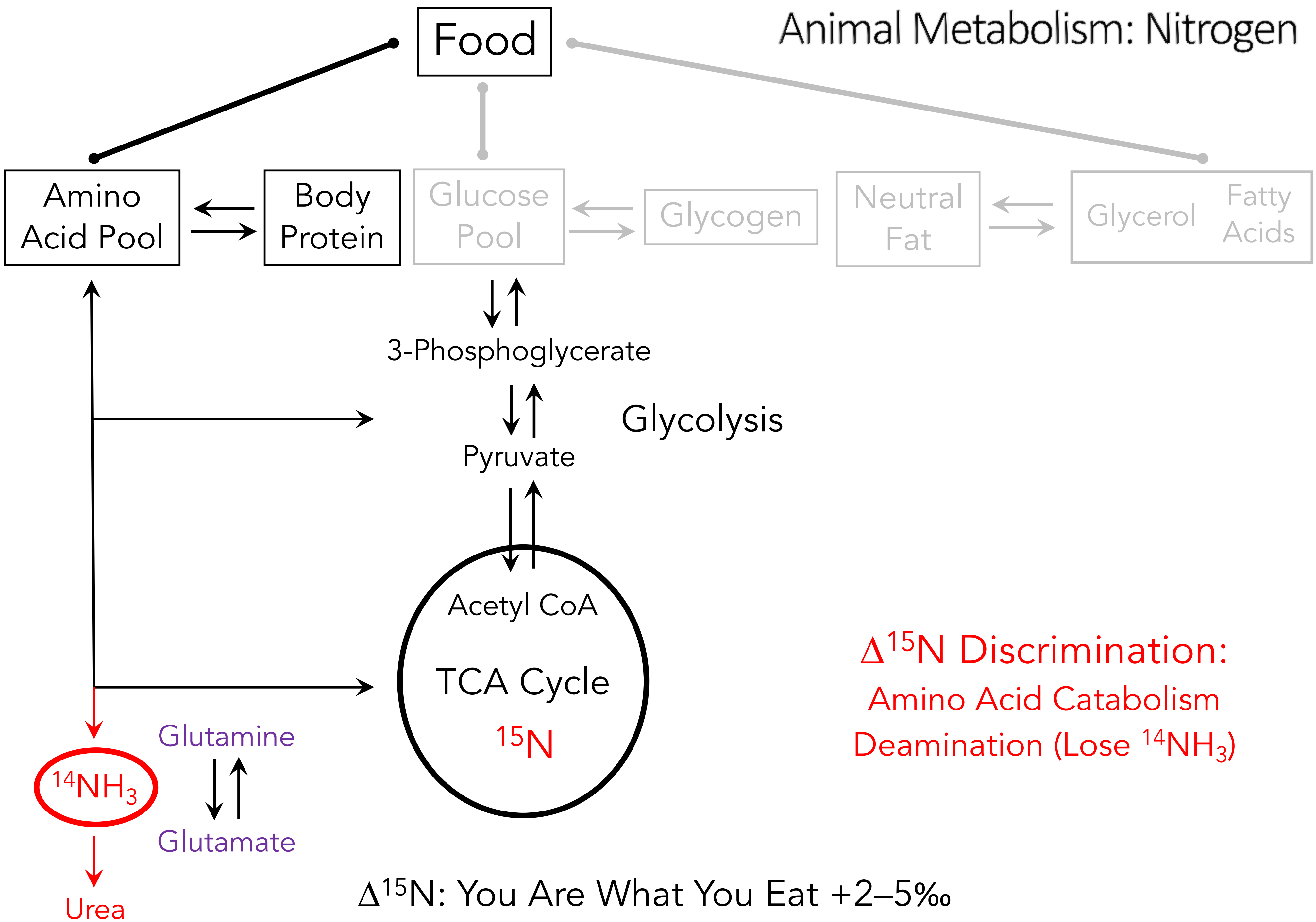
These 16 amino acids represent ~80–90% of amino acids in animal tissues

Animal Metabolism: Carbon



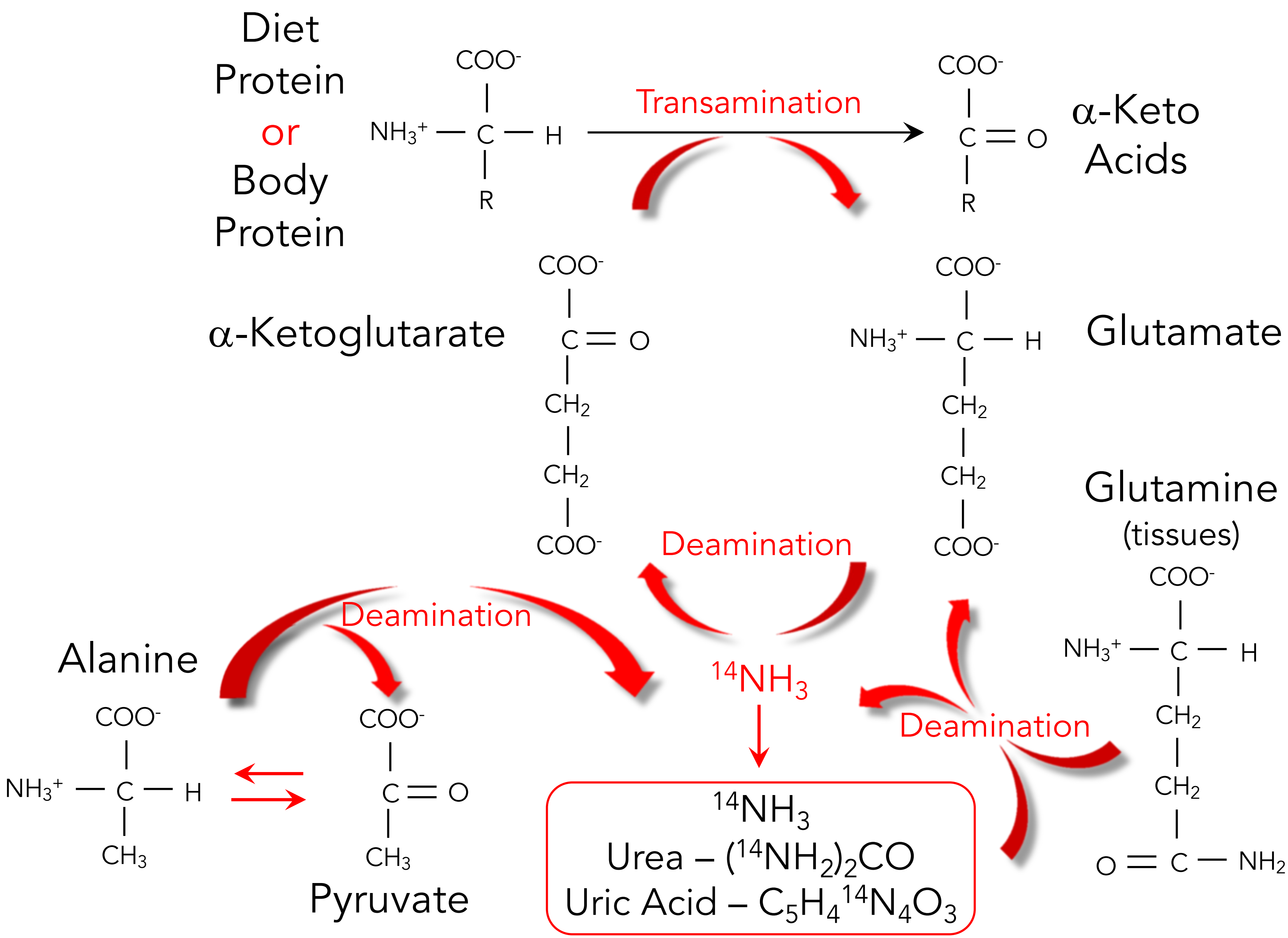
Animal Metabolism: Nitrogen



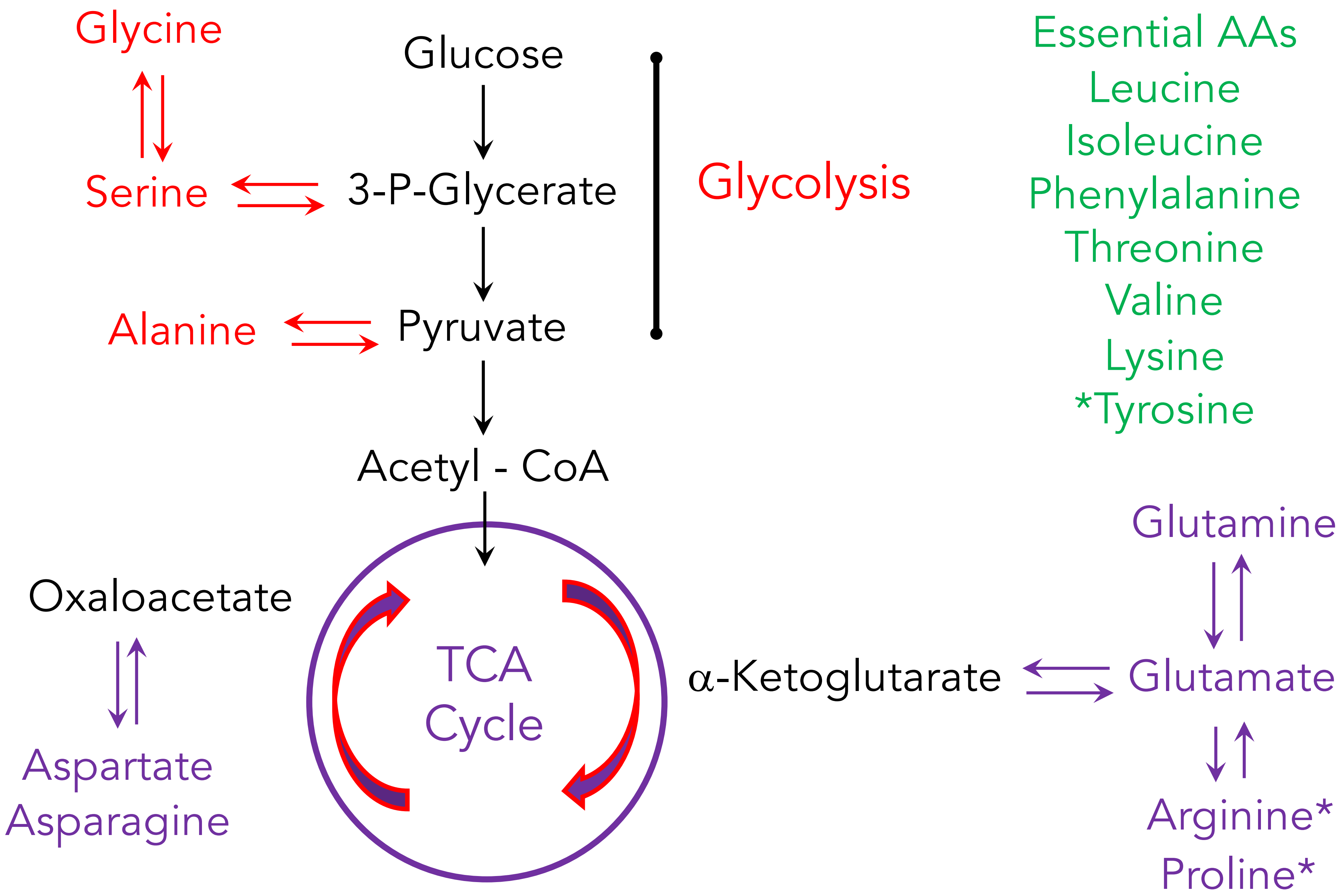

Animal Metabolism: Nitrogen
Food
Amino Acid Pool
Body Protein
Glucose Pool
Glycogen
Neutral Fat
Glycerol
Fatty Acids
3-Phosphoglycerate
Glycolysis
Pyruvate
Acetyl CoA
TCA Cycle
^{15}N
$\Delta^{15}N$ Discrimination:
Amino Acid Catabolism
Deamination (Lose $^{14}NH_3$)
$^{14}NH_3$
Glutamine
Glutamate
Urea
$\Delta^{15}N$: You Are What You Eat +2–5‰

Glutamine/Glutamate is Key: Transamination and Deamination

Direction influenced by [glutamate], [α-ketoglutarate], [NH_3], [enzymes]

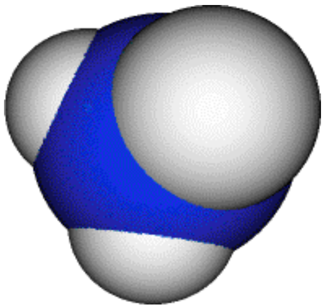


(Major) Amino Acid Metabolism



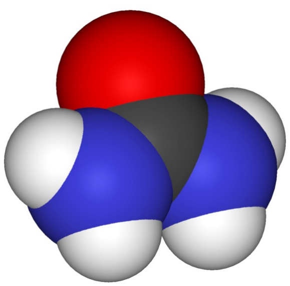
These 16 amino acids represent ~80–90% of amino acids in animal tissues

Major Driver of Variation in $\Delta^{15}N$: Form of Nitrogen Excreted



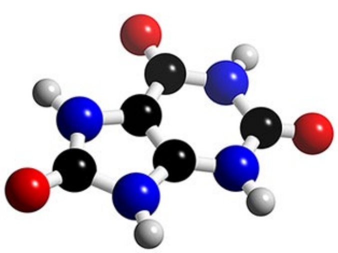
Ammonia – NH_3

- Simplest form to produce, but highly toxic
- Excreted by fully aquatic animals and invertebrates
- **Results in relatively small $\Delta^{15}N$**



Urea – $(NH_2)_2CO$

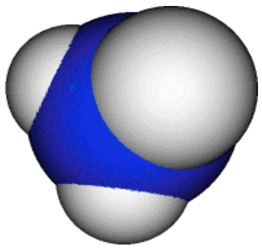
- More complex to synthesize, but relatively nontoxic
- Excreted by mammals and some marine fish (sharks)
- **Results in relatively large $\Delta^{15}N$**



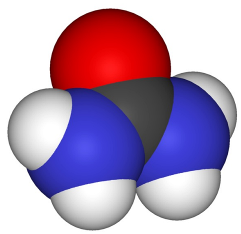
Uric Acid
$C_5H_4N_4O_3$

- Most complicated to synthesize, but least toxic form
- Excreted by birds, reptiles, and some insects
- **Results in relatively large $\Delta^{15}N$**

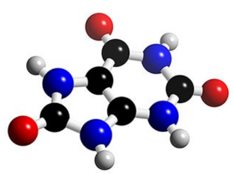
Major Driver of Variation in $\Delta^{15}N$: Type of Nitrogen Excreted



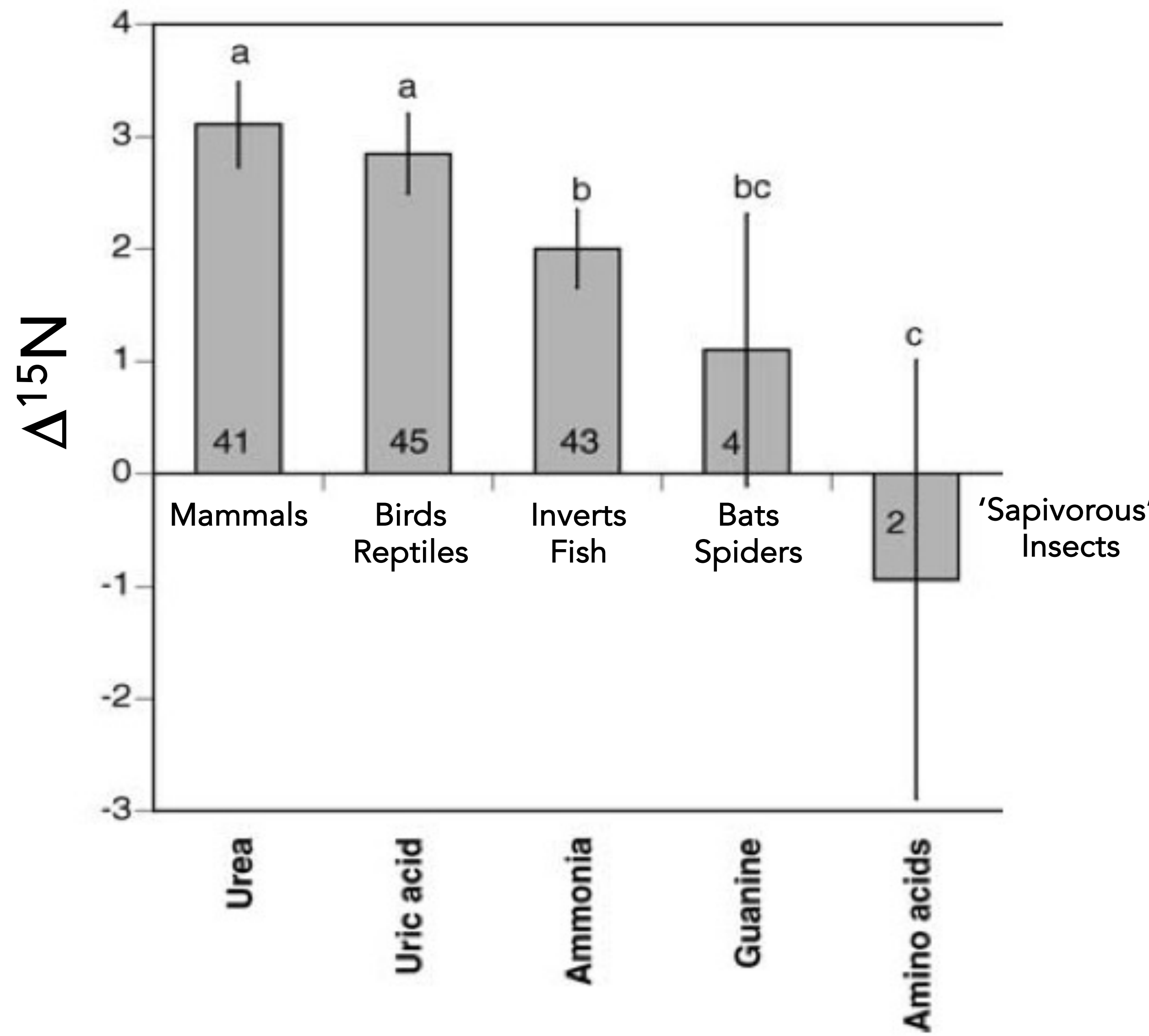
Ammonia – NH_3



Urea – $(NH_2)_2CO$



Uric Acid – $C_5H_4N_4O_3$



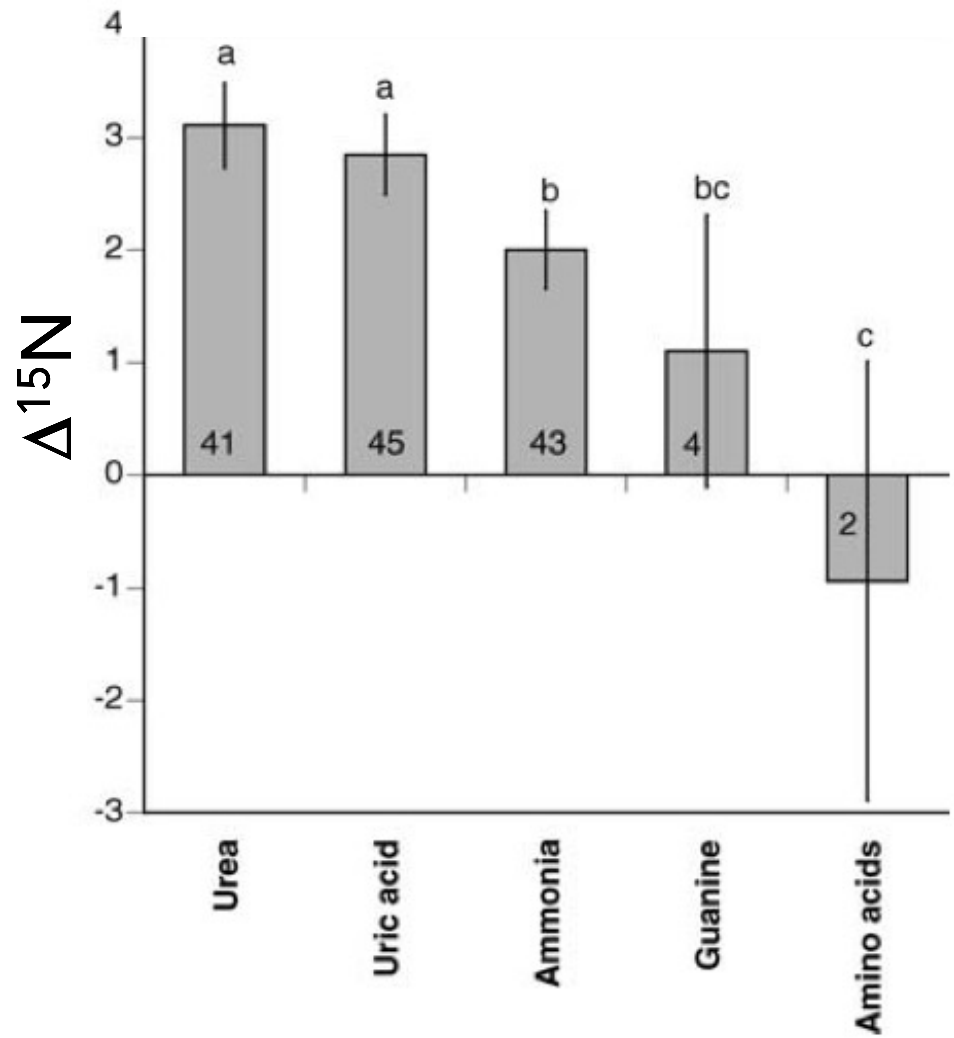
Consumers have higher isotopic values than their food

Animals preferentially retain ^{15}N and excrete ^{14}N

Vanderklift and Ponsard 2003

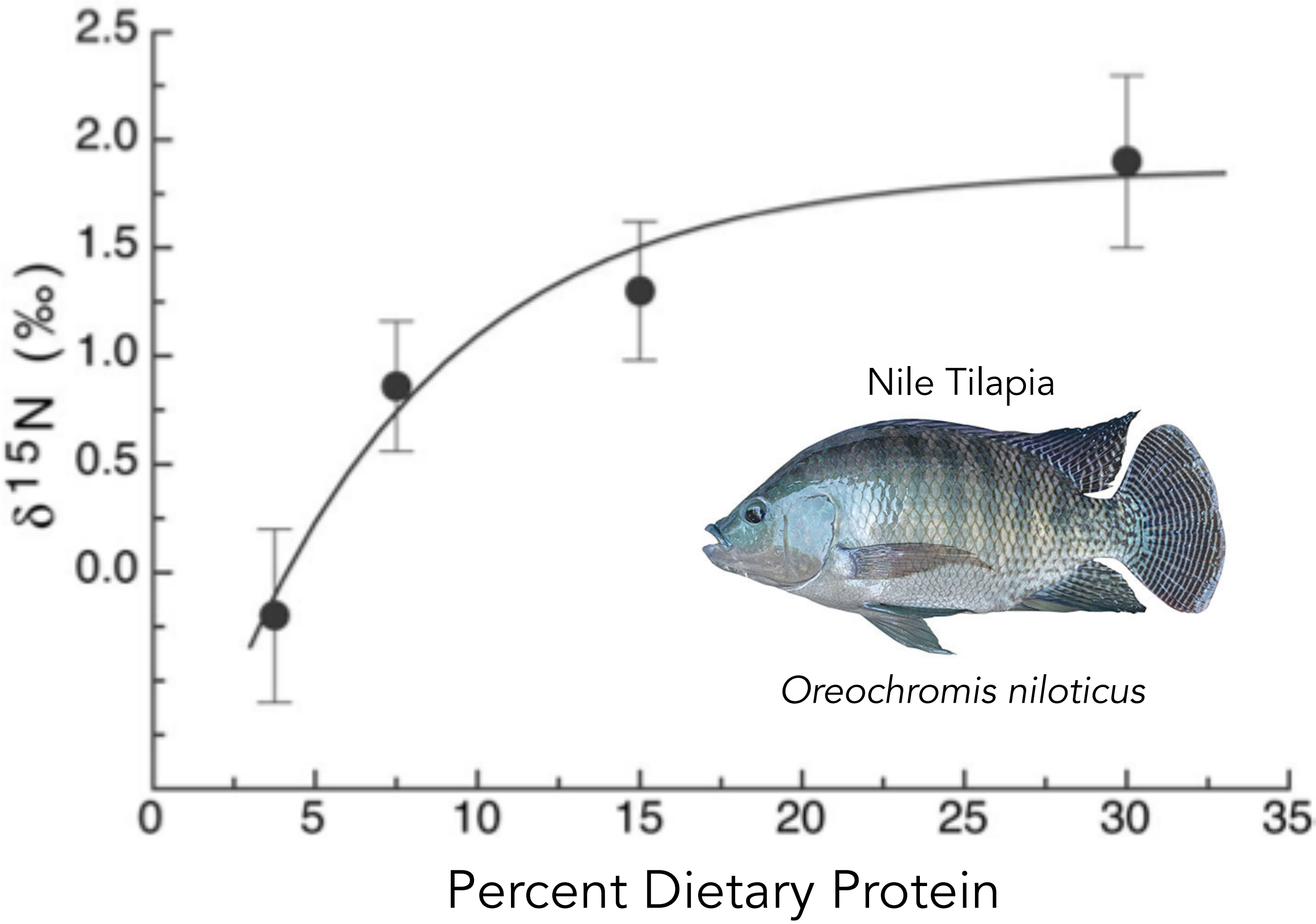
Other Factors Controlling Variation in $\Delta^{15}N$

1. Form of Excreted Nitrogen
2. Dietary Protein Quantity
3. Dietary Protein Quality
4. Animal Nutritional Status



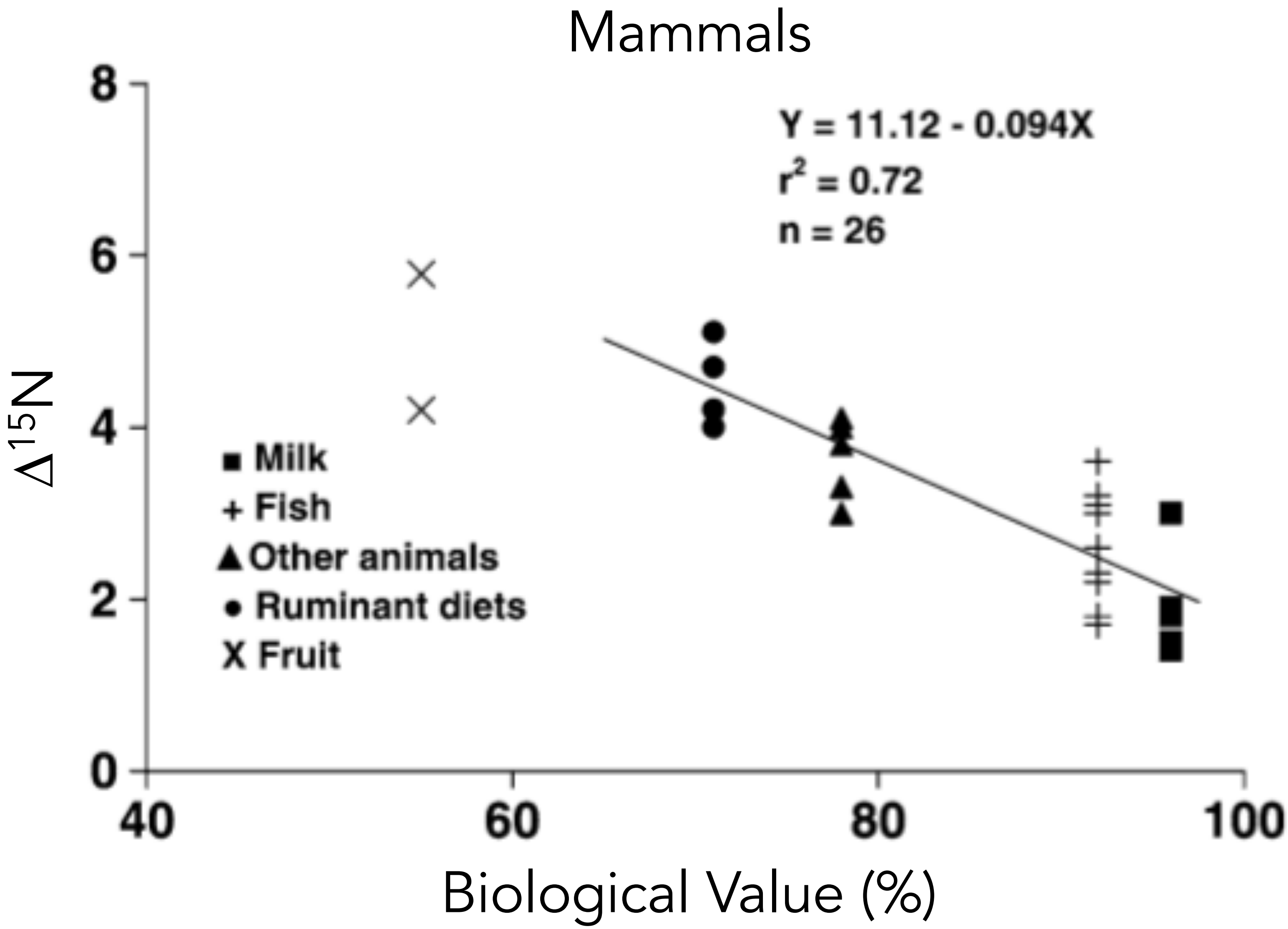
Vanderklift and Ponsard 2003

$\Delta^{15}N$ Increases with Dietary Protein Content



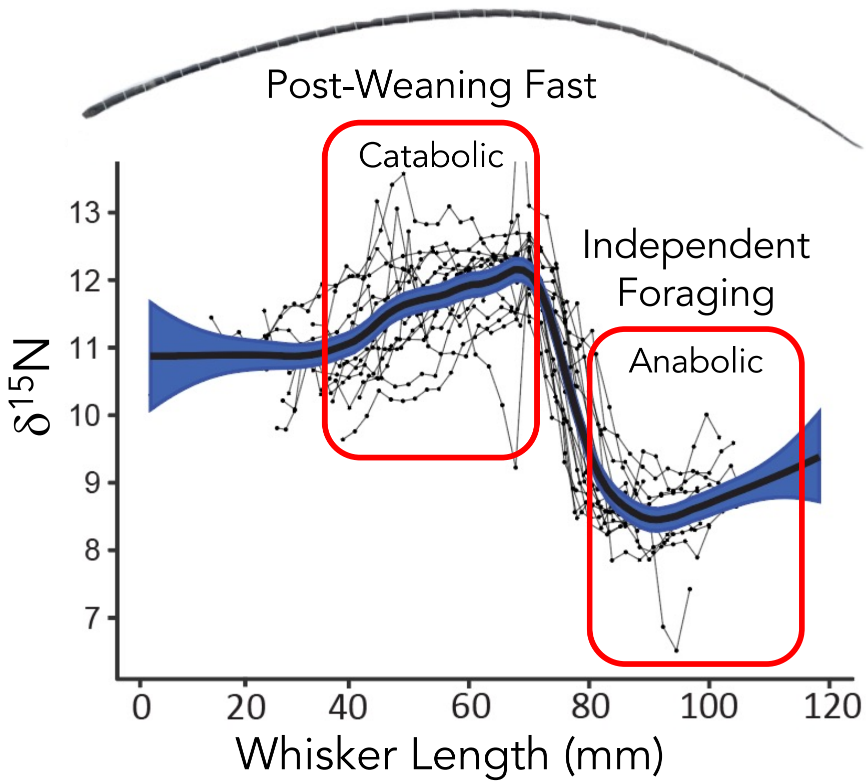
Kelly and Martinez del Rio 2010

$\Delta^{15}N$ Increases with Dietary Protein Quality



Robbins et al. 2005

$\Delta^{15}N$ Increases with Negative Nitrogen Balance



Marion Island, South Africa

Lubcker

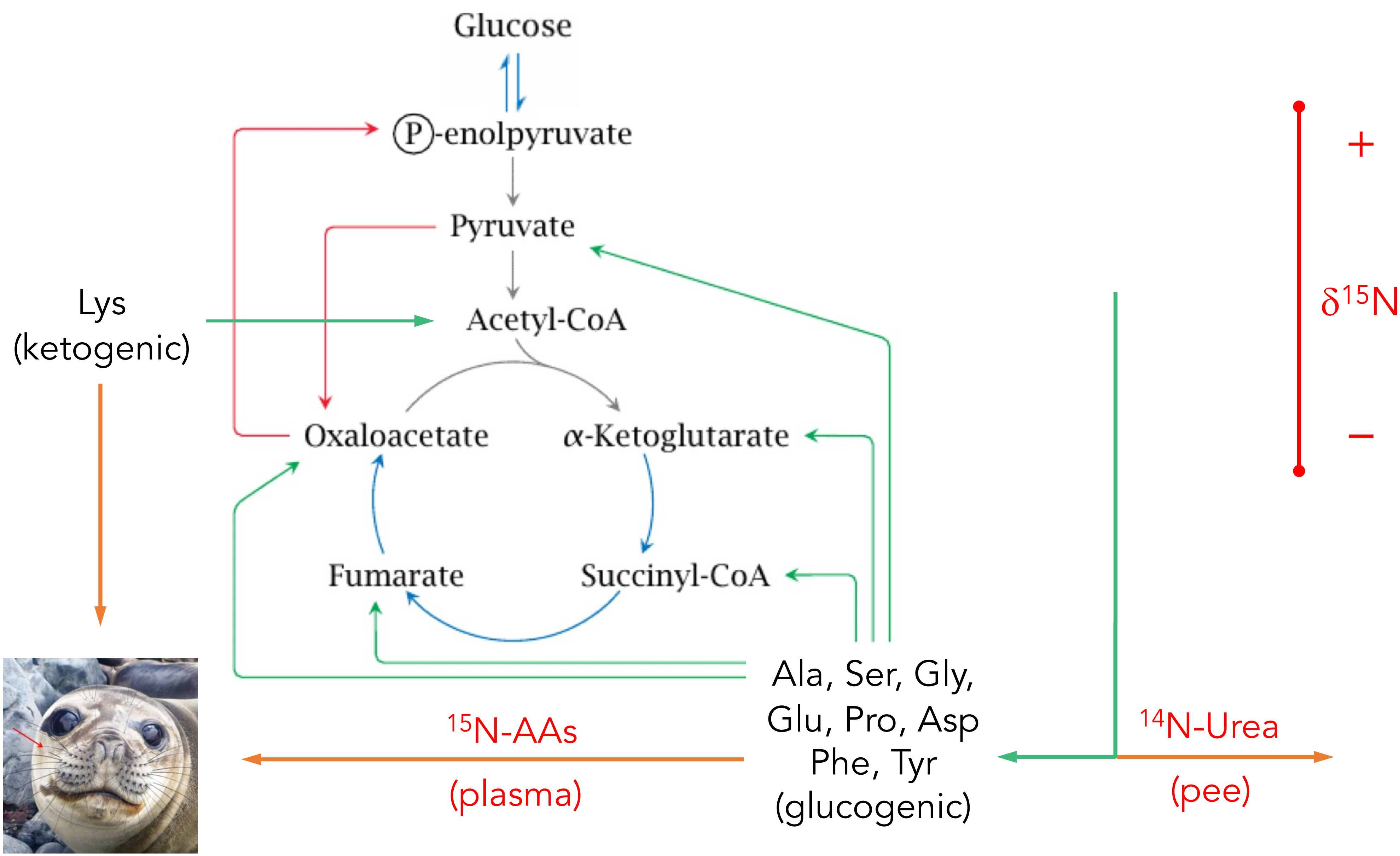
de Bruyn

Whiteman

Mirounga leonina

Lubcker et al. 2016, 2017, 2020

Gluconeogenesis: A Critical Pathway



Take Home Message(s): Bulk Tissue $\delta^{15}N$

Consumers have higher isotopic values than their food
Animals retain ^{15}N, excreting ^{14}N via NH_3, urea, and uric acid.

$\Delta^{15}N$ varies with dietary protein content, protein quality, and catabolism:
$\Delta^{15}N$ increases positively with dietary protein content
$\Delta^{15}N$ decreases with increasing dietary protein quality
$\Delta^{15}N$ increases with increasing catabolism of endogenous protein (muscle).

Interpretation of isotope data relies on knowing which factors control the assimilation, synthesis, and incorporation of isotopes into tissues.