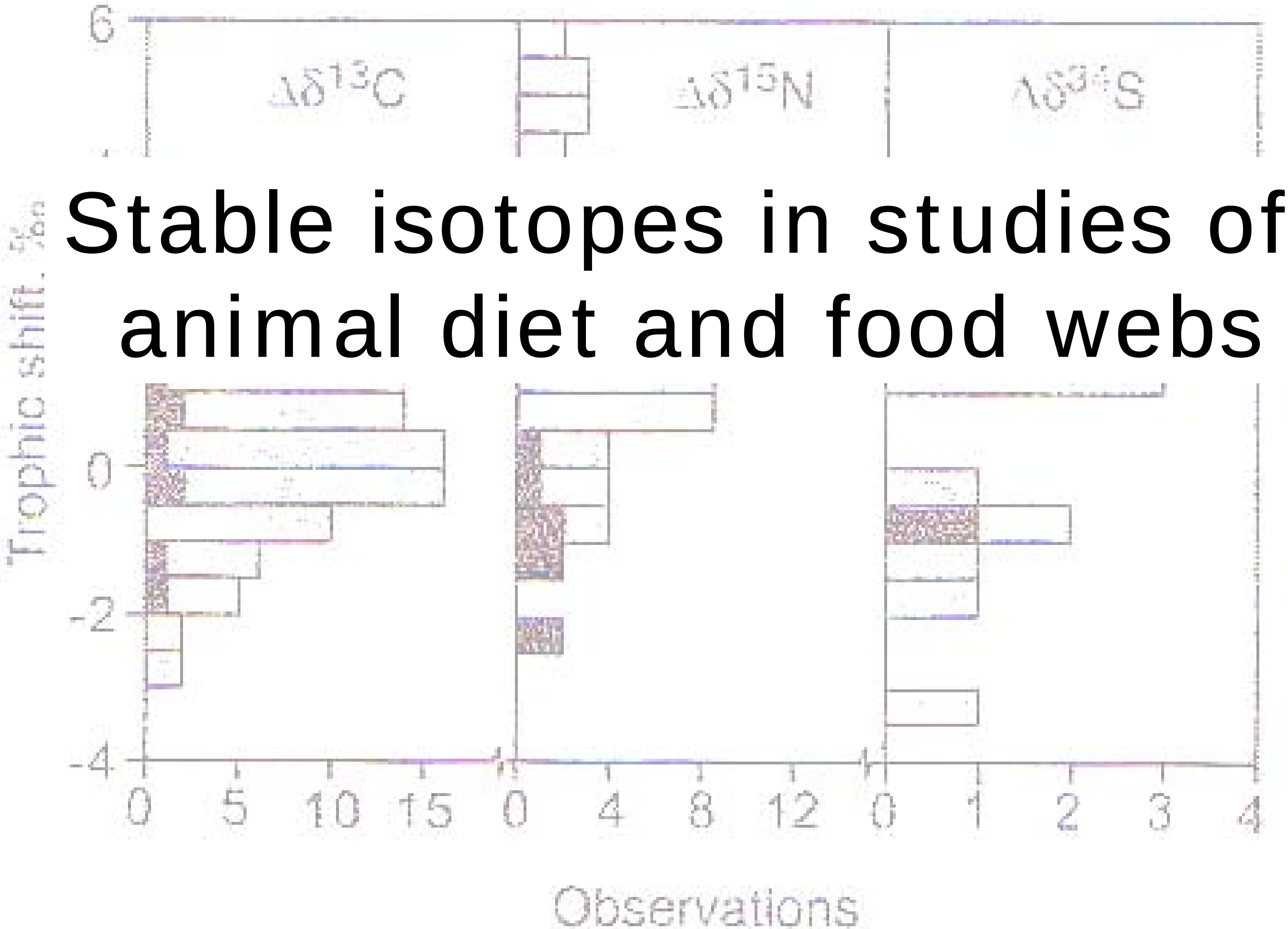
Wolfgang Wanek

# Stable isotopes in studies of animal diet and food webs



# Enrichment of $^{13}C$ and $^{15}N$ against diet

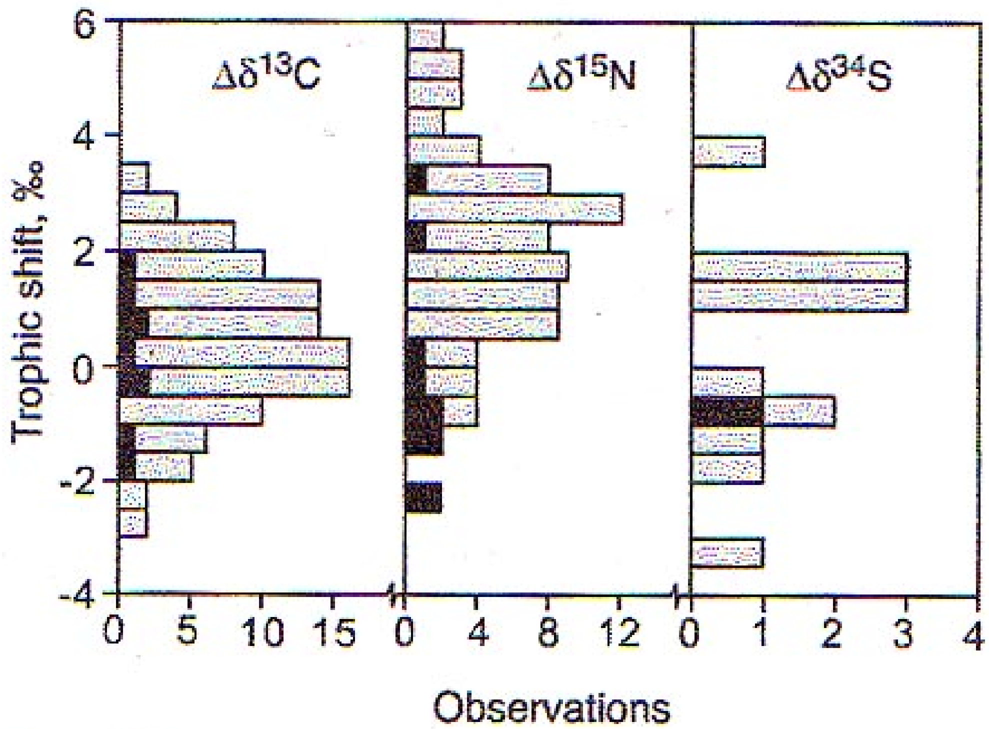



Fig. 1. Histograms for estimates of trophic shift for C, N, and S. Fluid-feeding consumers are indicated by dark bars. Statistical outliers (see Table 1 and Appendix 1) are not included.

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**Trophic level enrichment**

$\delta^{13}C$ +0.4±0.12 ‰ (n=111)

$\delta^{15}N$ +2.0±0.20 ‰ (n=83)

$\delta^{34}S$ +0.4±0.52 ‰ (n=13)

Dietary information ($\delta^{13}C$) versus trophic level information ($\delta^{15}N$)

BUT: large spread of values


McCutchan et al. 2003
Oikos 102: 378-390

# Food webs – trophic level enrichment in $^{13}C$ and $^{15}N$

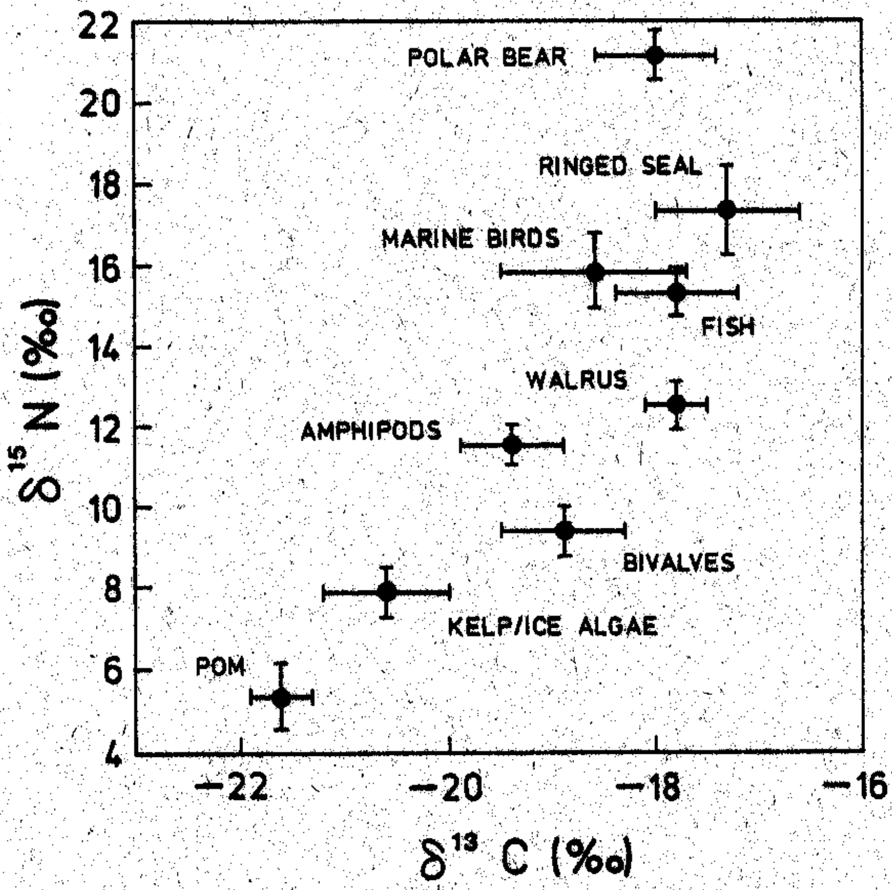



Fig. 2. Relationship of $\delta^{13}C$ and $\delta^{15}N$ values of groups of marine food-web organisms from the Barrow Strait-Lancaster Sound study area. Amphipod sample excludes *Stegocephalus inflatus* and marine-bird sample excludes glaucous gull. Sample sizes are as per Table 1

**Arctic marine foodweb (NW Territories, Canada)**

Foodweb base: POM, particulate organic matter (algae, bacteria, dead matter) and kelp/ice algae

Up to top predator: polar bear

Hobson & Welch 1992
MEPS 84:9

# Food webs – trophic level enrichment in $^{15}N$

Number of trophic levels in an ecosystem calculated by dividing the full range of $\delta^{15}N$ by TLE (3‰ here)

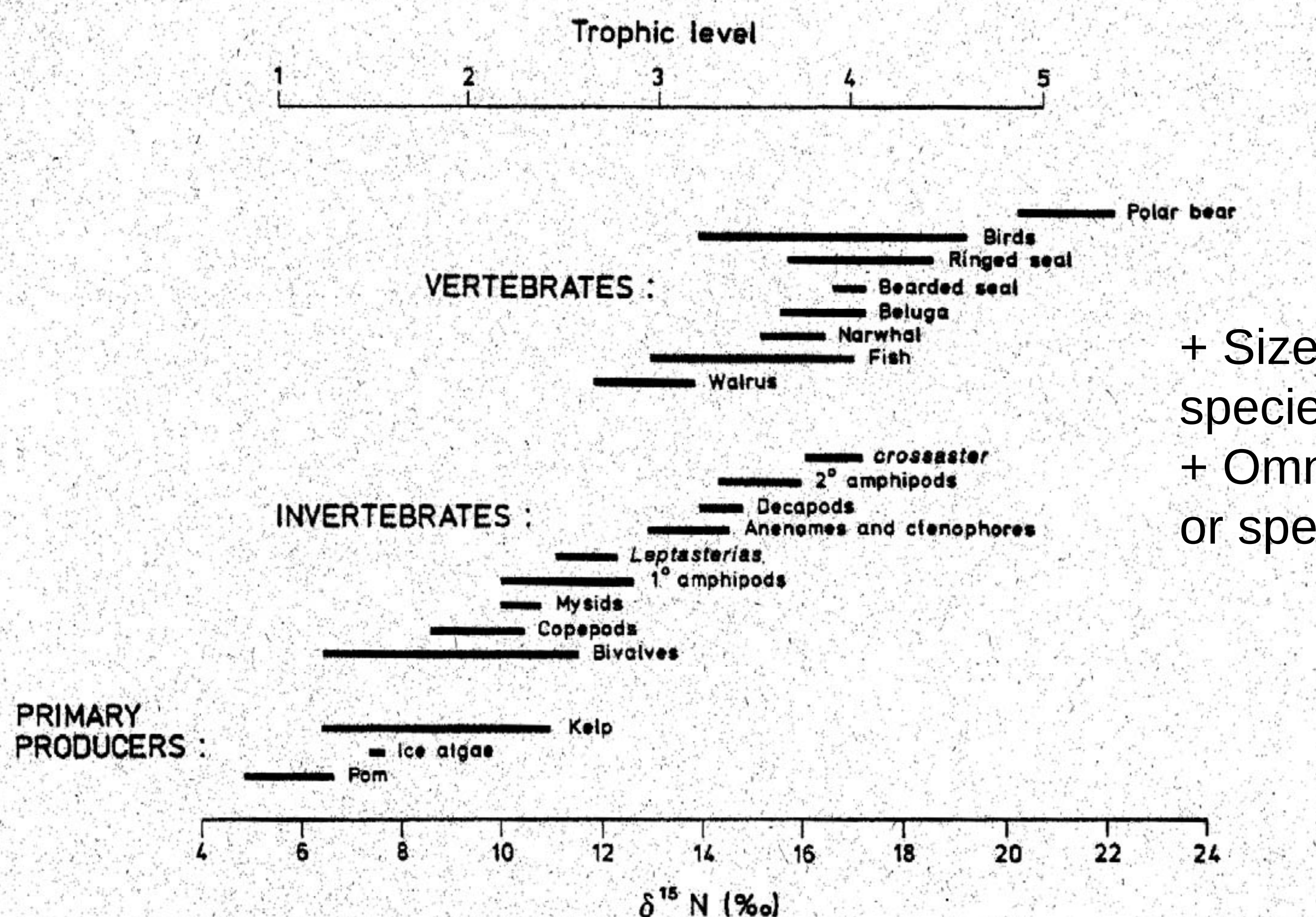



Fig. 3. Ranges of $\delta^{15}N$ values for marine organisms from Barrow Strait-Lancaster Sound and their associated trophic positions according to an isotopic model using a trophic enrichment value of + 3.8 ‰ (not applicable to marine birds)

+ Size of trophic niche of a species (SD)
+ Omnivory (generalists) or specialists

Hobson & Welch 1992
MEPS 84:9

# $^{15}N$ Amino acid enrichment – nonessential versus essential amino acids



TABLE 1. Values of $\delta^{15}N$ of bulk samples and amino acids of *B. plicatilis* and *T. suecica*.

| $\delta^{15}N$ source | First sampling: *T. suecica* (Food source) | First sampling: *B. plicatilis* (Consumer) | Second sampling: *T. suecica* (Food source) | Second sampling: *B. plicatilis* (Consumer) |
|---|---|---|---|---|
| Bulk sample | −1.9 | 0.1 | −1.7 | −0.2 |
| Amino Acids | | | | |
| Alanine | 0.5 ± 0.7 | 4.8 ± 0.1 | −1.6 ± 0.1 | 4.0 ± 0.4 |
| Aspartic acid | −0.5 ± 0.3 | 4.6 ± 0.2 | −0.6 ± 0.4 | 3.2 ± 0.4 |
| Glutamic acid | −0.4 ± 0.2 | 6.5 ± 0.4 | −0.1 ± 0.3 | 6.4 ± 0.3 |
| Glycine | −4.7 ± 0.4 | −3.2 ± 0.4 | −4.4 ± 0.3 | −4.1 ± 0.8 |
| Isoleucine† | −0.8 ± 0.5 | 3.3 ± 0.1 | −1.3 ± 0.9 | 2.4 ± 0.4 |
| Leucine† | −0.4 ± 0.8 | 2.8 ± 0.1 | −1.5 ± 0.3 | 2.0 ± 0.3 |
| Lysine† | −1.1 ± 0.4 | 0.7 ± 0.4 | −1.8 ± 0.2 | −0.4 ± 1.2 |
| Phenylalanine† | −5.3 ± 0.2 | −4.2 ± 0.2 | −4.3 ± 0.4 | −4.8 ± 1.0 |
| Proline | 0.1 ± 0.3 | 4.3 ± 0.2 | −0.4 ± 0.2 | 3.3 ± 0.3 |
| Serine | −7.8 ± 0.6 | −7.1 ± 0.2 | −7.8 ± 0.3 | −6.9 ± 0.3 |
| Threonine† | −2.4 ± 0.4 | −3.4 ± 0.4 | −2.3 ± 0.1 | −4.1 ± 0.5 |
| Tyrosine | −2.2 ± 0.6 | −3.3 ± 0.6 | −2.5 ± 0.3 | −3.1 ± 0.1 |
| Valine† | 1.8 ± 0.3 | 4.5 ± 0.1 | 1.0 ± 1.5 | 5.6 ± 0.3 |

*Notes:* Samples were collected on two successive days after determining that bulk values were at a steady state. Values for bulk samples are from CFIRMS analysis (standard deviation is typically ± 0.2‰). Values for amino acids are means ± 1 SE from three analyses of each sample by GCIRMS. Aspartic acid includes asparagine. Glutamic acid includes glutamine.

† Amino acids commonly required in animal diets (essential amino acids.)

McClelland & Montoya 2002
Ecology 83:2173

# $^{15}N$ Amino acid enrichment
# – nonessential versus essential amino acids

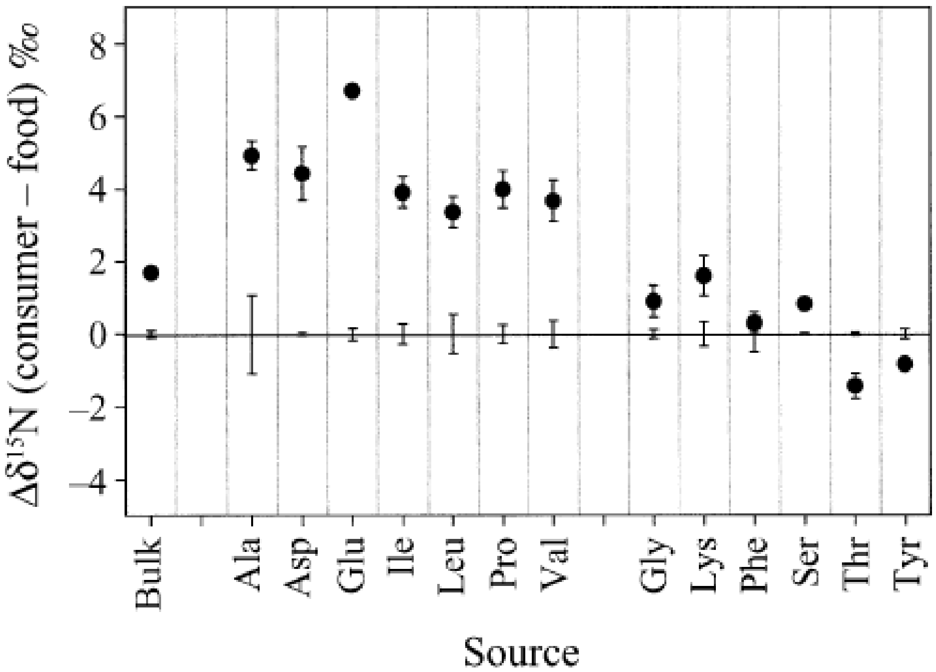



FIG. 1. Differences in stable N isotope values ($\Delta\delta^{15}N$) of bulk material and individual amino acids between consumer (*B. plicatilis*) and food source (*T. suecica*). Points are means from two sampling dates, and error bars reflect the range of values from *B. plicatilis* (on points) and *T. suecica* (on zero line). Amino acids are grouped into those that show changes greater than the bulk material and those that change less than the bulk material. Abbreviations are: Ala, alanine; Asp, aspartic acid; Glu, glutamic acid; Ile, isoleucine; Leu, leucine; Pro, proline; Val, valine; Gly, glycine; Lys, lysine; Phe, phenylalanine; Ser, serine; Thr, threonine; Tyr, tyrosine.

$^{15}N$ enrichment in „non-essential“ amino acids between 4 and 7 permil (metabolic N recycling)

No such enrichment in „essential“ amino acids (isotopic signature of food source)

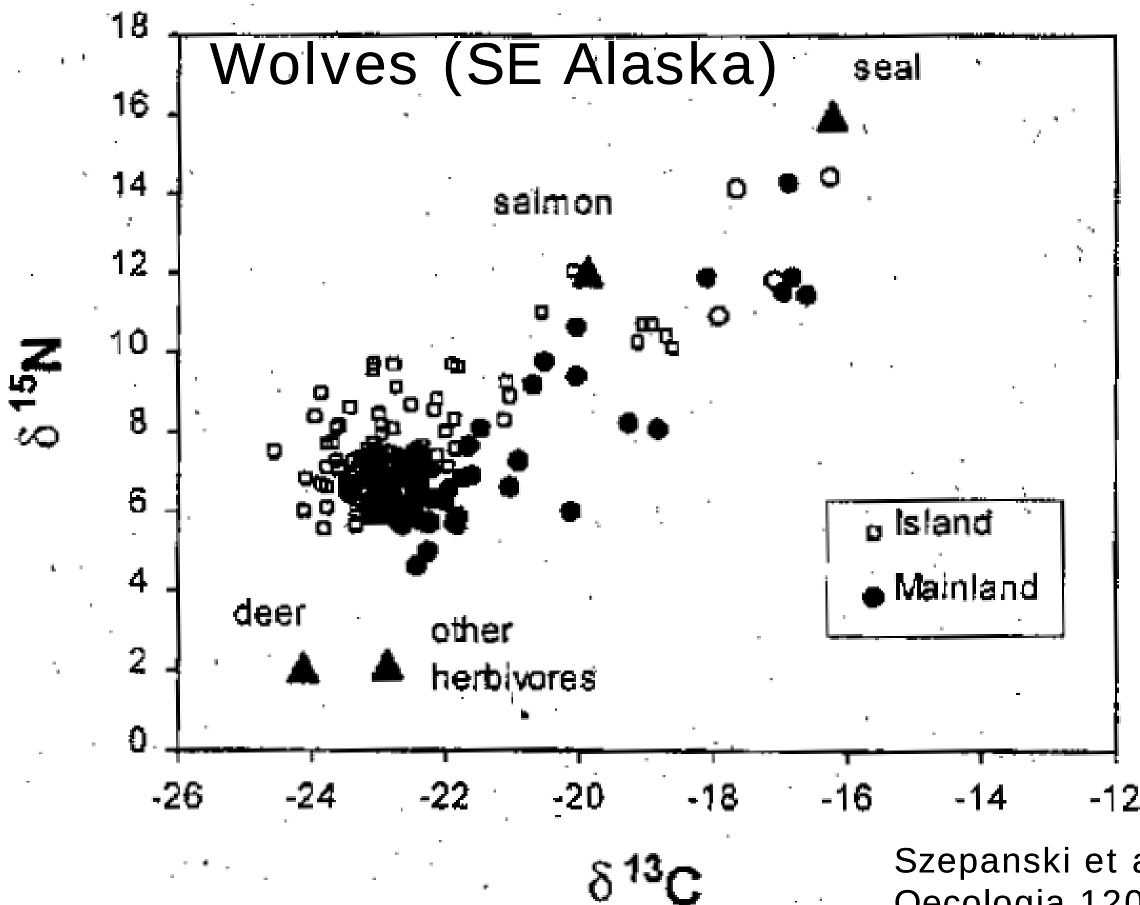
$\Delta\delta^{15}N$ Glu – Phe approx. 7 permil per trophic level
i.e. a measure of trophic level enrichment without knowing the exact food source and its isotopic composition

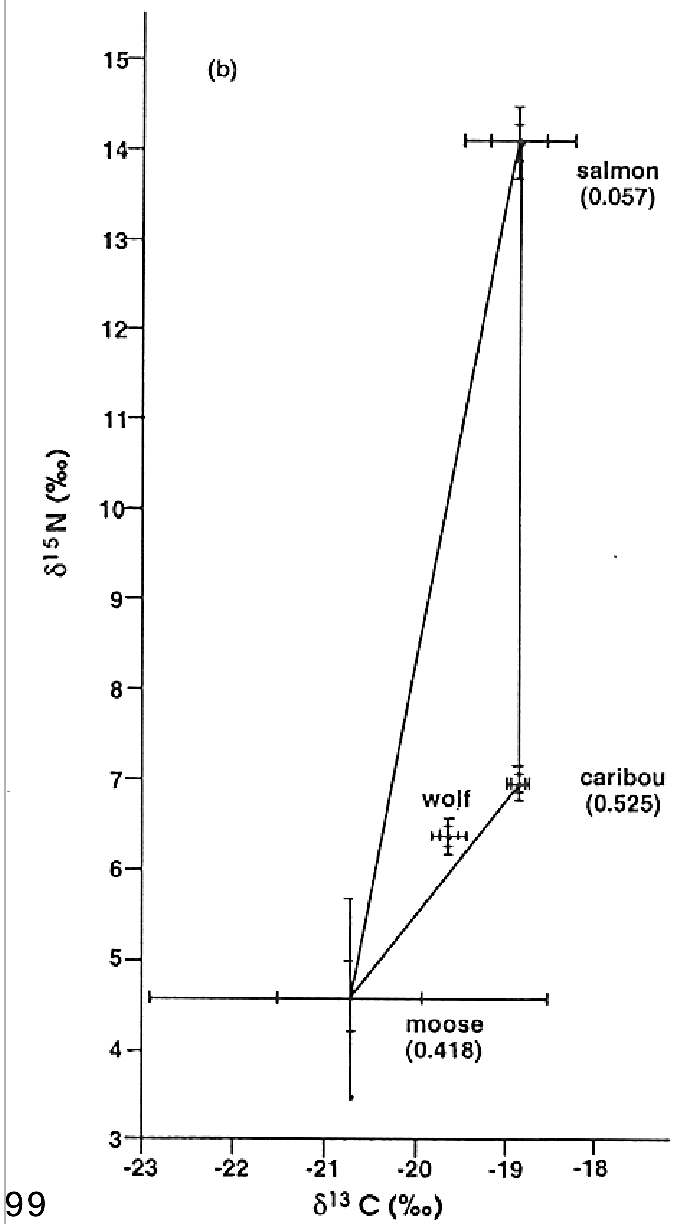
McClelland & Montoya 2002
Ecology 83:2173

# Animal diet – two-isotope mixing models to calculate fractions of mixed diets

**Partitioning of wolf diets**

Two isotopes allow the differentiation between three diet sources (see right). Account for trophic level enrichment




Szepanski et al. 1999
Oecologia 120: 327

# $C_3$ versus $C_4$ diets – Browsers and grazers

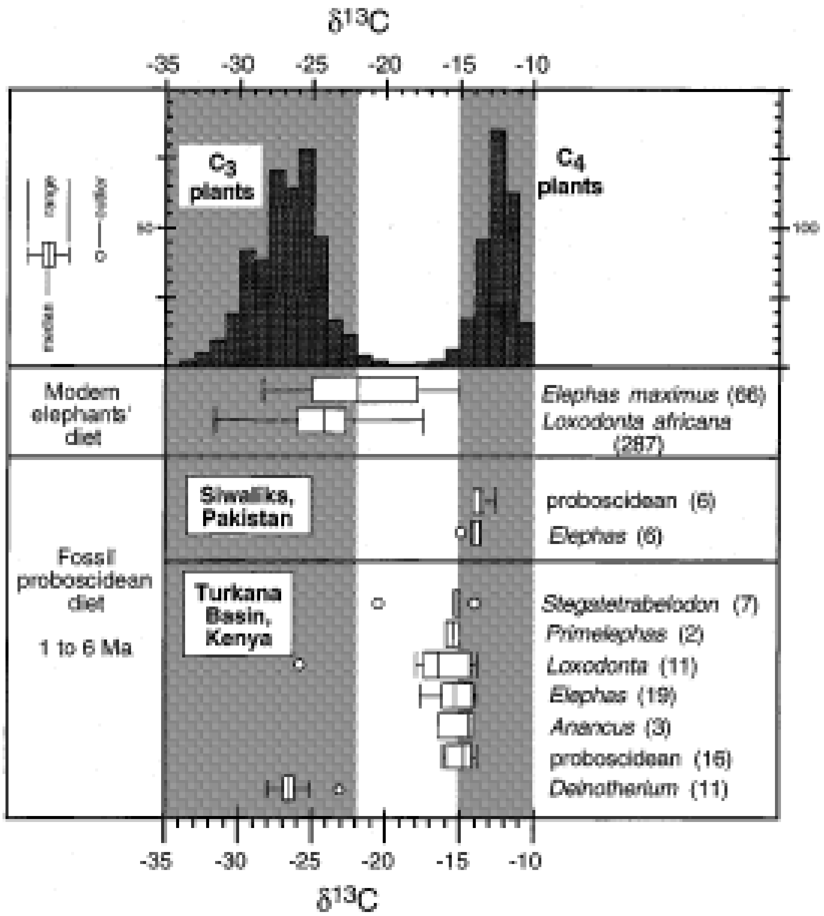



Fig. 3 Estimated diets for modern *Loxodonta* and *Elephas* compared to the estimated diets for fossil proboscideans. Modern data from Figs. 1, 2. Fossil data for Africa from Table 2; fossil data from Pakistan from Stern et al. (1994), Morgan et al. (1994), and from this study

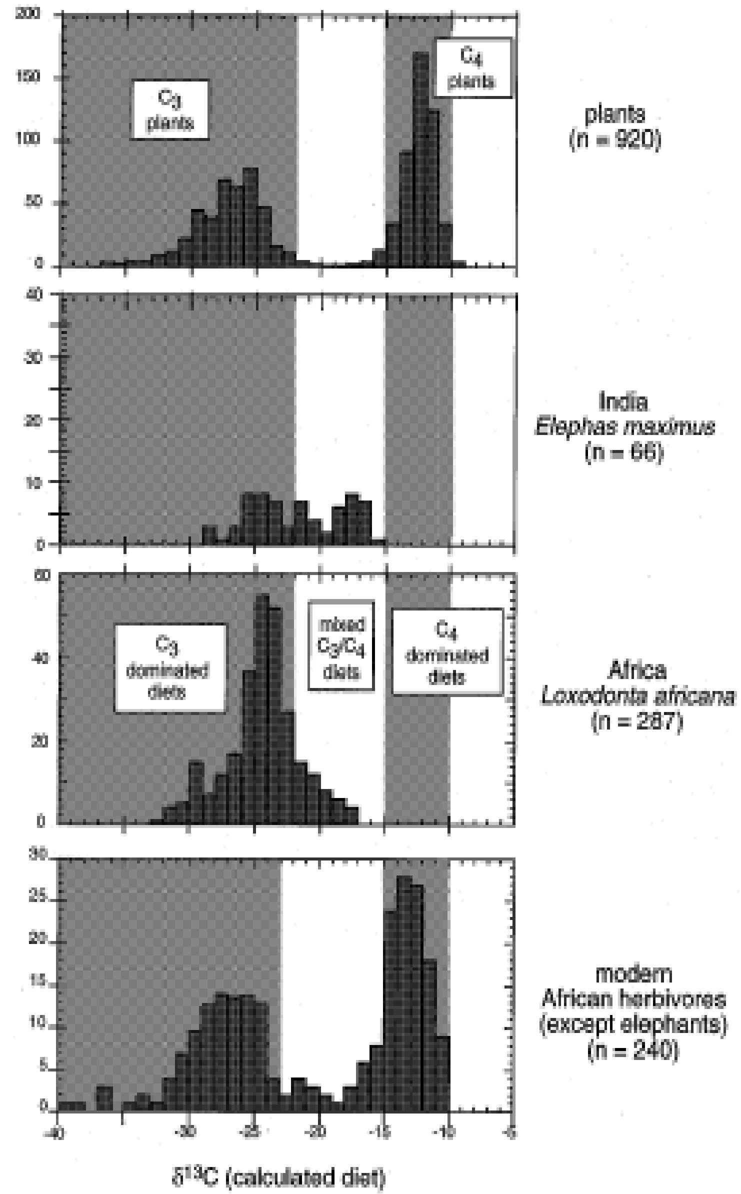
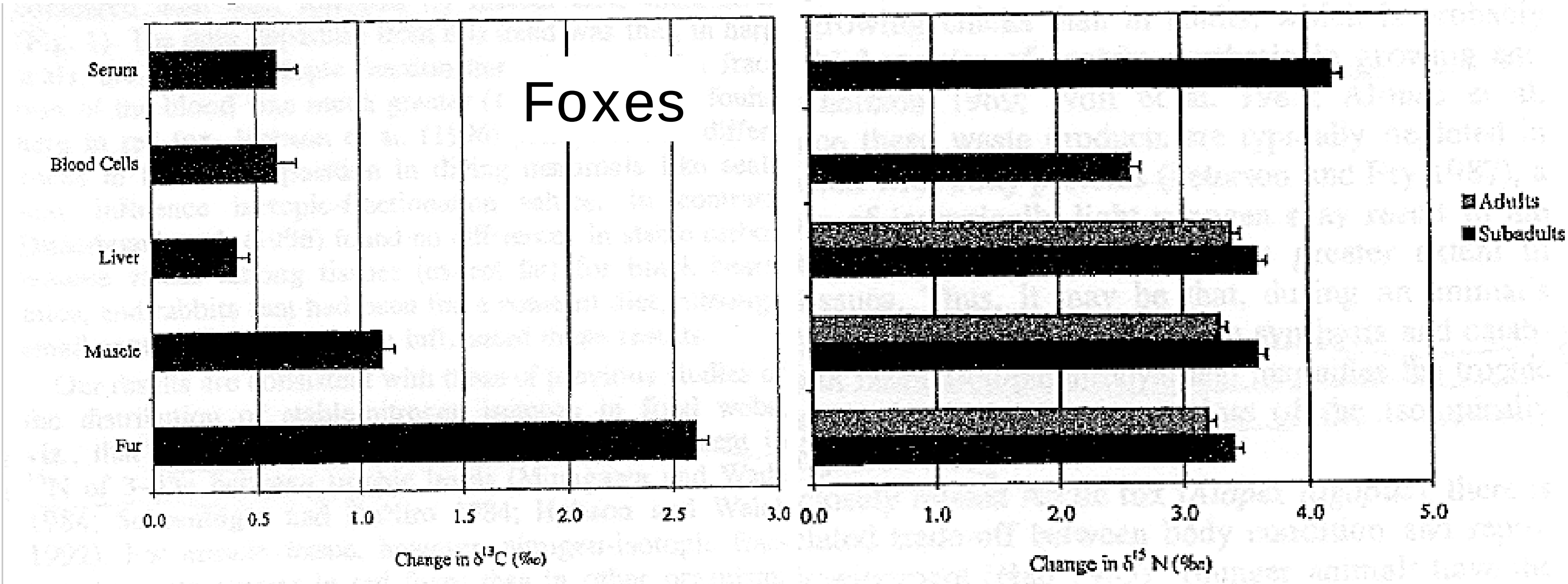



Fig. 1 Histograms showing $\delta^{13}C$ for modern plants, and estimated diets calculated from tooth enamel or collagen for modern elephants and for modern African herbivores using fractionation as described in the text. Data sources are this study, and from Sukumar et al. (1987), van der Merwe et al. (1988, 1990), Vogel et al. (1990a, b), Sukumar et al. (1987), Sukumar and Ramesh (1992, 1995), Koch et al. (1995), and Bocherens et al. 1996b)

Cerling et al. 1999
Oecologia 120: 364

# Isotopic differences between tissues




$\Delta_{diet\ -\ tissue}$ $\Delta_{diet\ -\ tissue}$

Fir, bones, enamel, and horn are isotopically distinct from diet

Roth & Hobson 2000
Can. J. Zool. 78: 848

# Tissue turnover and time integration of dietary isotope signals

Different dietary time integration of tissues such as blood, liver, muscles, bone collagen, hair keratin of gerbil ([Wüstenrennmaus](Wüstenrennmaus))

Hair ($t_{1/2}$=47 d)

Brain (28 d)

Muscle (27 d)

Liver (6 d)

Fat (15 d)

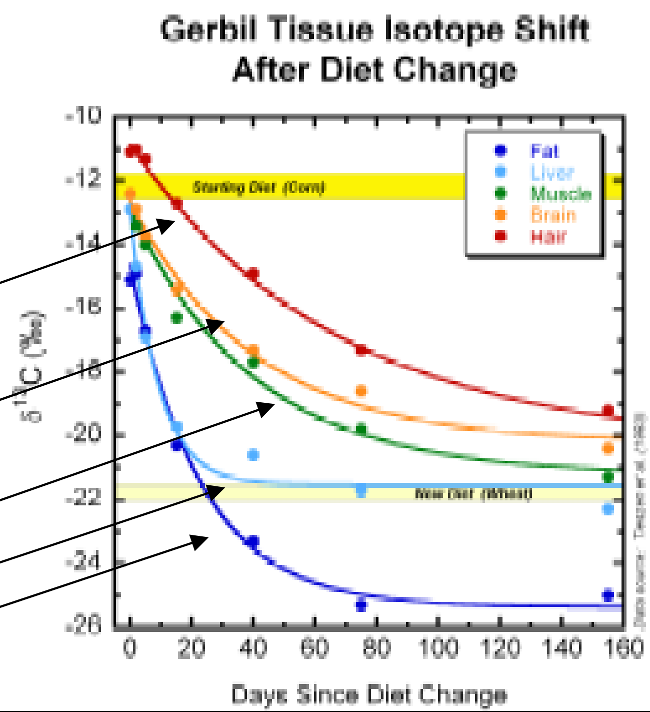
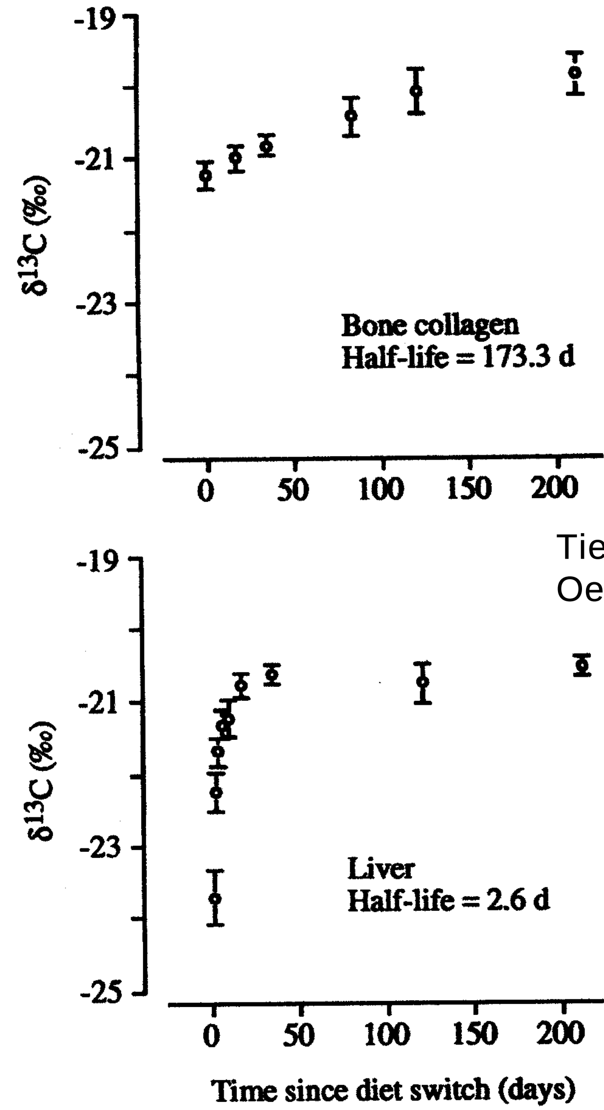
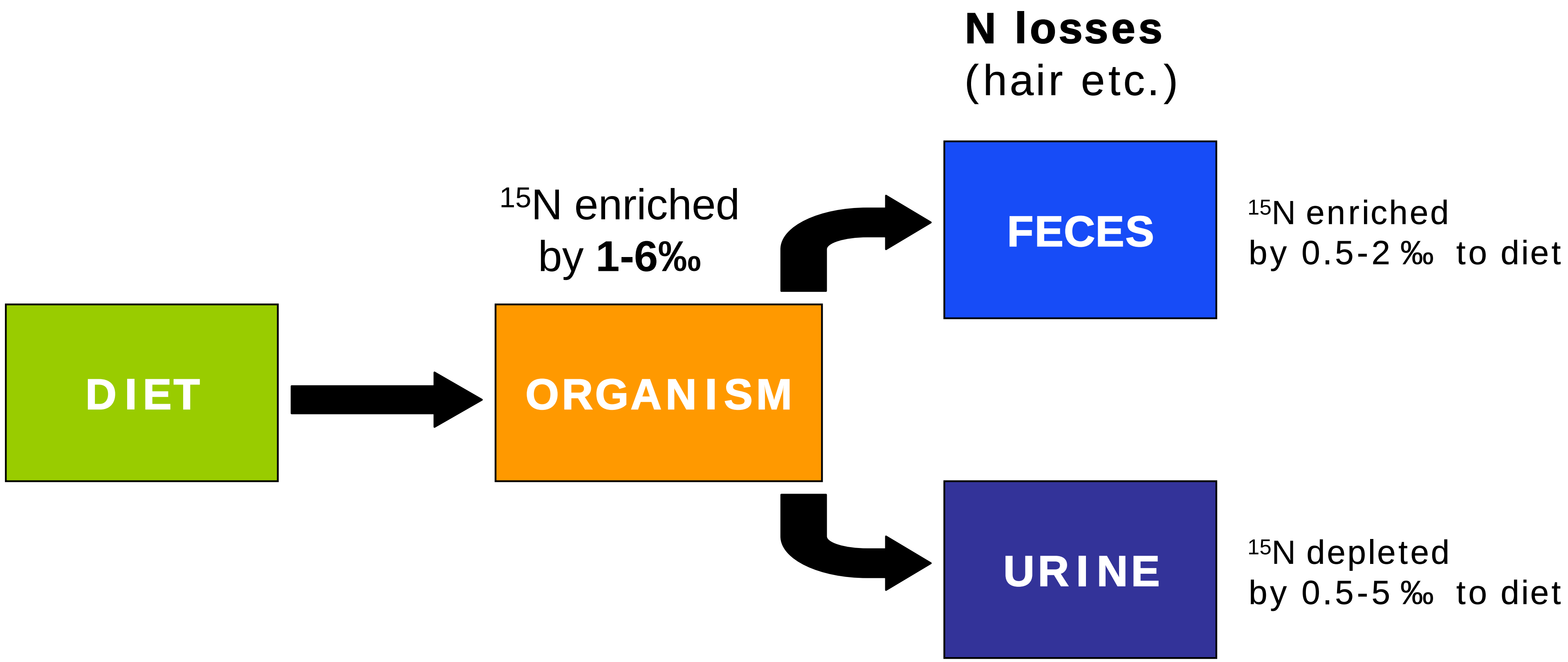



Figure 4. When a gerbil's diet is switched to food with a different $\delta^{13}C$ value, its tissues change over time to reflect this. This happens as carbon in the tissues is replaced. Some tissues show this change more rapidly than others. For example, liver tissue achieves the $\delta^{13}C$ value of the new diet in less than 80 days, whereas hair takes well over twice as long.




Tieszen et al. 1983
Oecologia 57: 32

# Herbivore diet and N losses




Deamination/transamination remove $^{14}N$ preferentially that is excreted in urine and enriches $^{15}N$ in body protein (key enzymatic step unknown)

# Herbivore diet and diet protein content

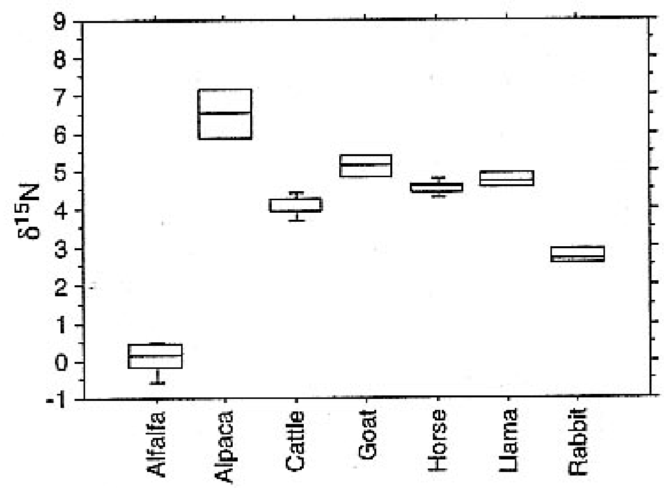



Figure 2. Box plot showing $\delta^{15}N$ values for the alfalfa diet and six mammalian herbivore species that had been eating this diet. The range in trophic enrichment is between 2.8‰ and 6.4‰. Note the difference between the alpacas and rabbits is 3.6‰, more than enough to be attributed to a shift in trophic level. The hindgut fermenting rabbits have lower $\delta^{15}N$ values than all of the foregut fermenters, possibly because they digest a lower percentage of their microflora.



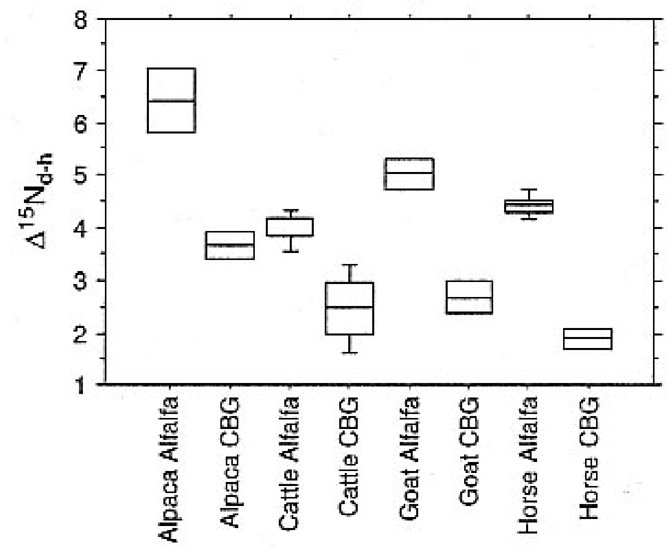


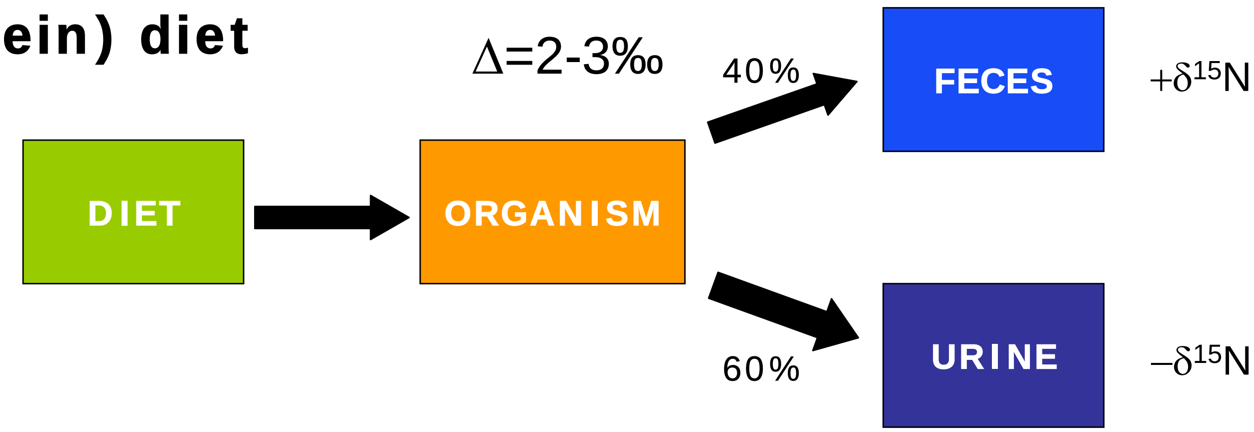

Figure 3. Box plot showing diet-hair fractionation ($\Delta_{d-h}$) for herbivores eating high-protein alfalfa diets and low-protein coastal bermudagrass (CBG) diets. Note the consistently higher diet-hair fractionation for animals eating the high-protein alfalfa.

Alfalfa 19% crude protein
Bermuda grass 9% crude protein

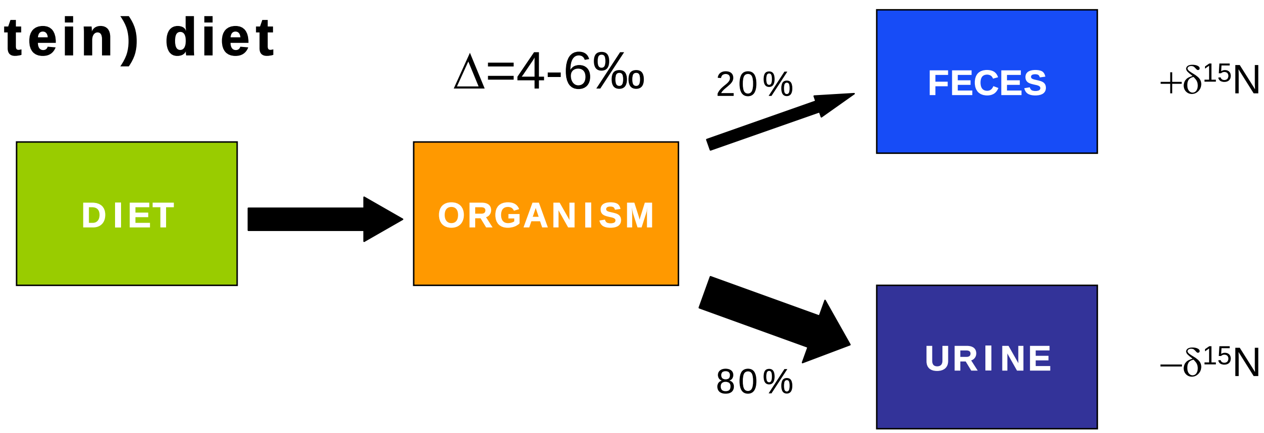
Sponheimer et al. (2003)
Int. J. Osteoarchaeol. 13: 80

# Herbivore $^{15}N$ enrichment with low and high protein diets

**Low N (protein) diet**




**High N (protein) diet**



# You are what you eat, plus a few permilles?

Mr. T.E. Cerling goes west (from USA to mongolia)........ Changing food - changing beard C isotope signatures

or **You are what you eat ?**

**Hair as a chronological archive**
+ continuous growth (0.4 mm/day)
+ biologically inactive after formation
+ resistant to degradation

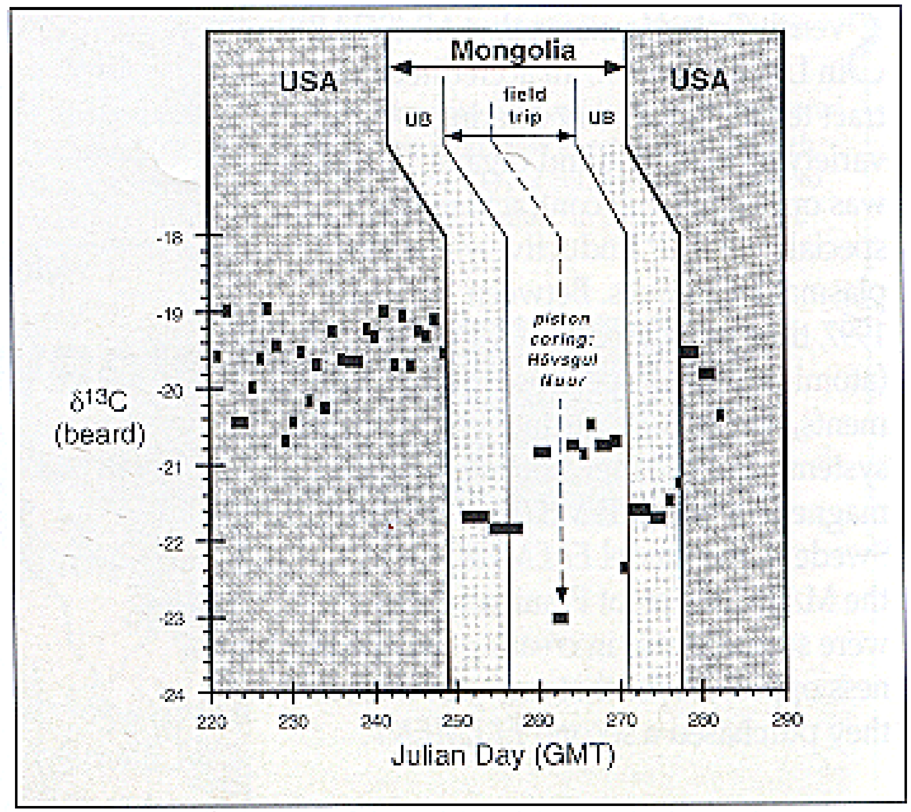



*Figure 1: This figure plots the carbon isotopic composition of beard hair (expressed as $\delta^{13}C$) vs date that the hair was collected. The kinks in the Mongolian time lines correspond to the six-day time lag between hair formation and its eruption through the skin surface.*

# Human diet –
# The human food web

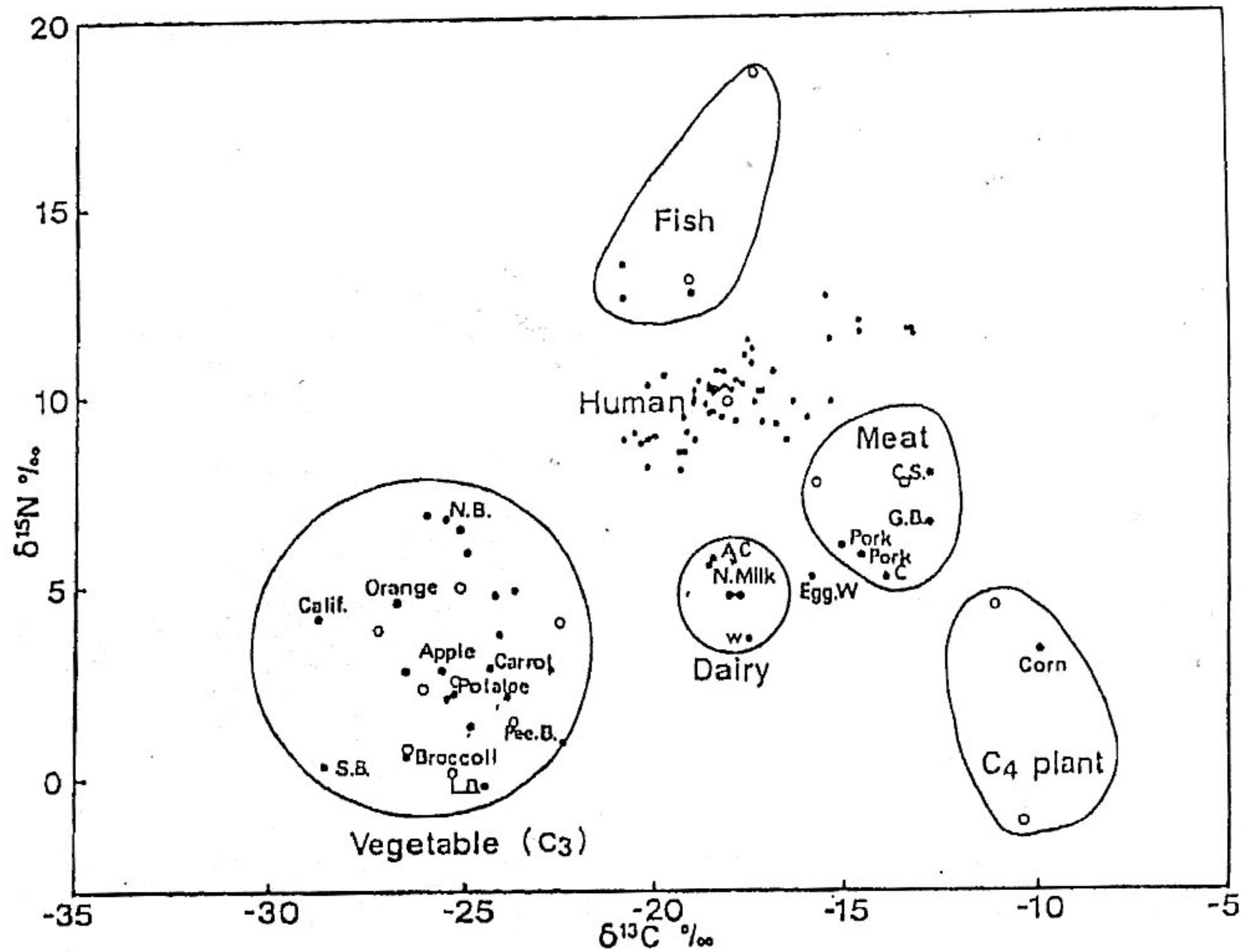



**FIGURE 8.** The distribution of carbon and nitrogen isotopes in a human food web. Open circles: Japanese foods. (From Minagawa, M. et al., *Chikyuu-Kagaku,* 2, 79, 1986. With permission.) Closed circles: American foods. (Adapted from Schoeller, D. A. et al., *Ecol. Food Nutrit.,* 18, 159, 1986.)

# Herbivorous versus omnivorous humans - Hair isotopic signatures

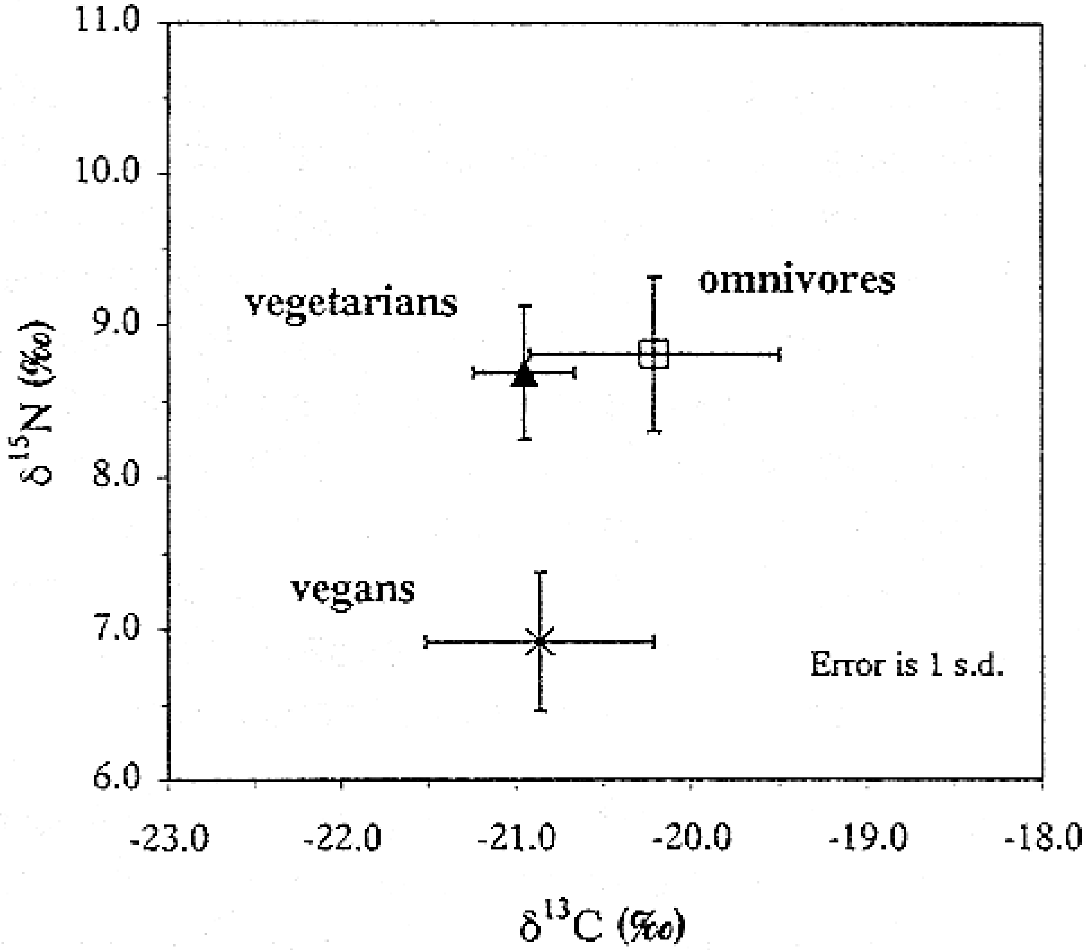



Fig. 2. Mean isotopic analyses for each dietary preference group.

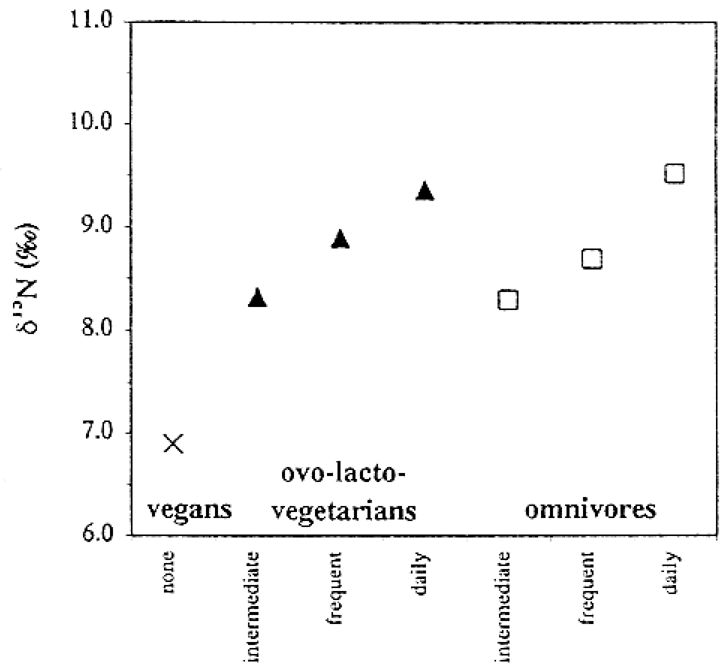



Fig. 3. Dependence of mean hair nitrogen isotopic values on the frequency of animal protein consumption for each dietary group.

Possibility to determine % animal protein intake


Macko et al. (1999)
Phil. Trans. R. Soc. London B 354: 65