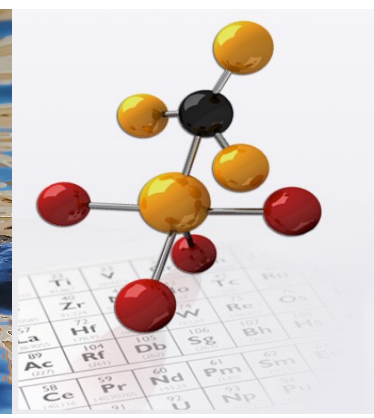
How Do We Study What Animals Eat?

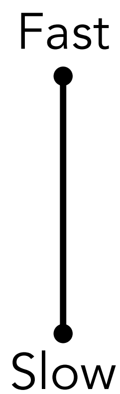
- Direct Observation
  - Pros: Rich data, can be collected at the individual level
  - Cons: Time- and cost-intensive, predation is difficult to observe
- Scat or Gut/Stomach Content Analysis
  - Pros: Captures diversity of diet
  - Cons: Snapshot, biased towards hard parts, invasive (stomach/gut)
- Chemical Proxies (Stable Isotope Analysis)
  - Pros: Integrates over a variety of timescales, non-invasive
  - Cons: Low resolution (does not capture prey taxonomic diversity)

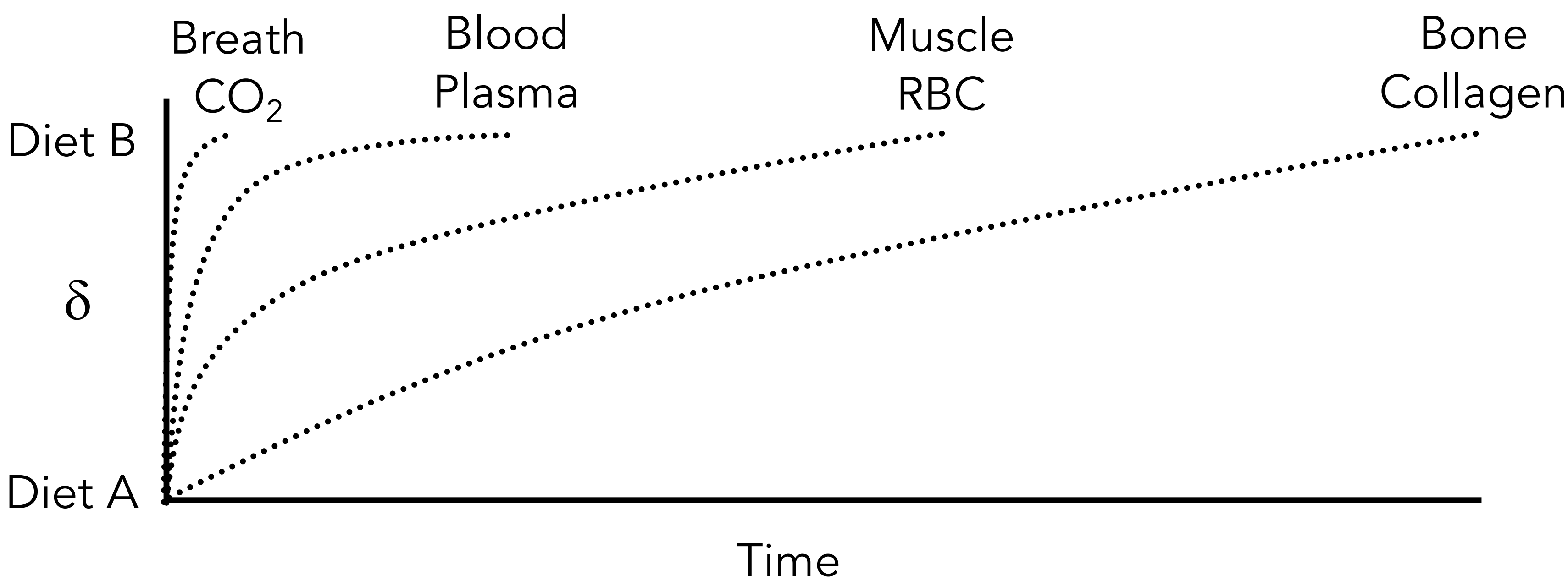




Isotopic Incorporation (aka Turnover)

Metabolically Active
(Continuous Turnover)

Breath (CO_2)
Blood Plasma & Liver
Skin
Red Blood Cells
Muscle
Bone Collagen





Isotopic Incorporation

Metabolically Active
(Continuous Turnover)
Breath (CO_2)
Blood Plasma & Liver
Skin
Red Blood Cells
Muscle
Bone Collagen

Metabolically Inert
(Short Time Periods)
Fur
Feathers

Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Breeding Season			Foraging Trip ←		Molting			Foraging Trip			

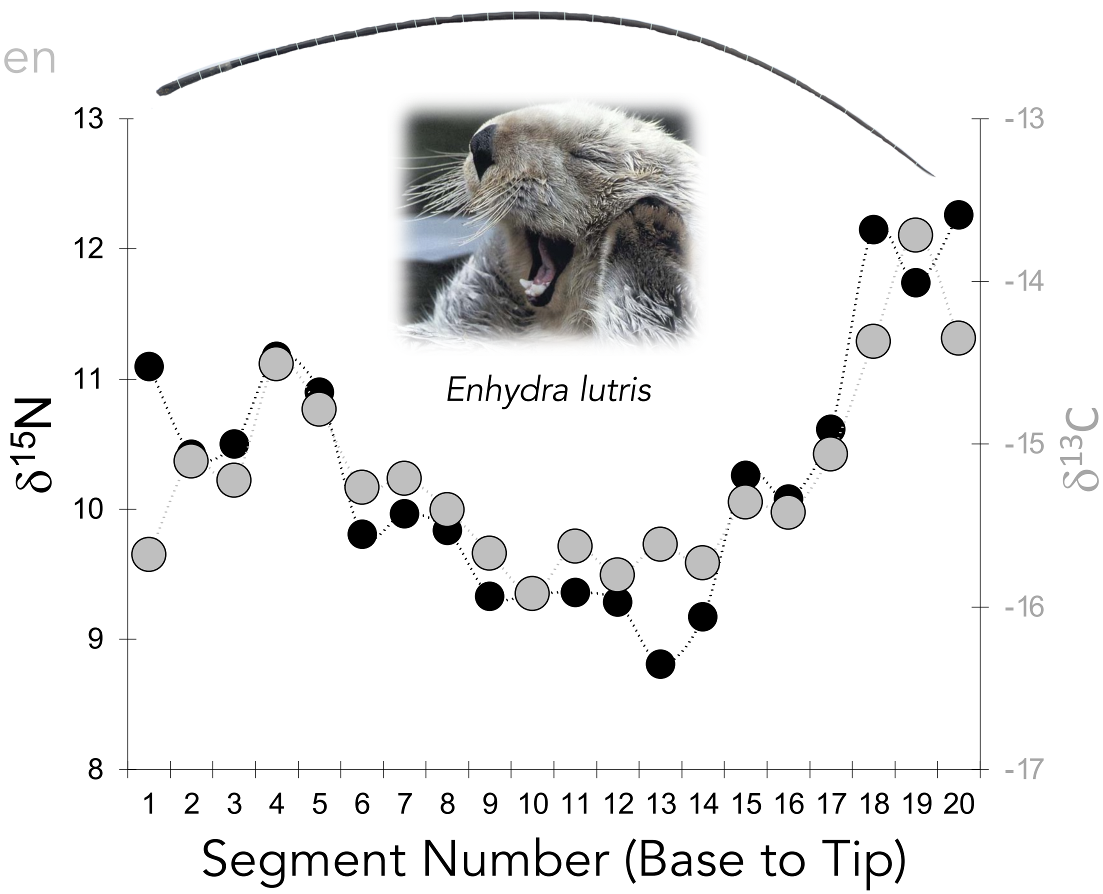
DO NOT EAT

Isotopic Incorporation

Metabolically Active
(Continuous Turnover)
Breath (CO_2)
Blood Plasma & Liver
Skin
Red Blood Cells
Muscle
Bone Collagen

Metabolically Inert
(Short Time Periods)
Fur
Feathers

Metabolically Inert
(Accretionary)
Tooth Dentin
Vibrissae
Baleen
Claws/Nails



Carefully Chose Which Tissue You Sample

Metabolically Active (Continuous Turnover)

Blood Plasma
Liver
Red Blood Cells
Muscle
Bone Collagen
Breath (CO_2)

Metabolically Inert (Short Time Periods)

Fur
Feathers

Metabolically Inert (Accretionary)

Tooth Dentin
Vibrissae
Baleen
Claws/Nails

What do you want to know?
Must think about life history, especially annual life cycle!

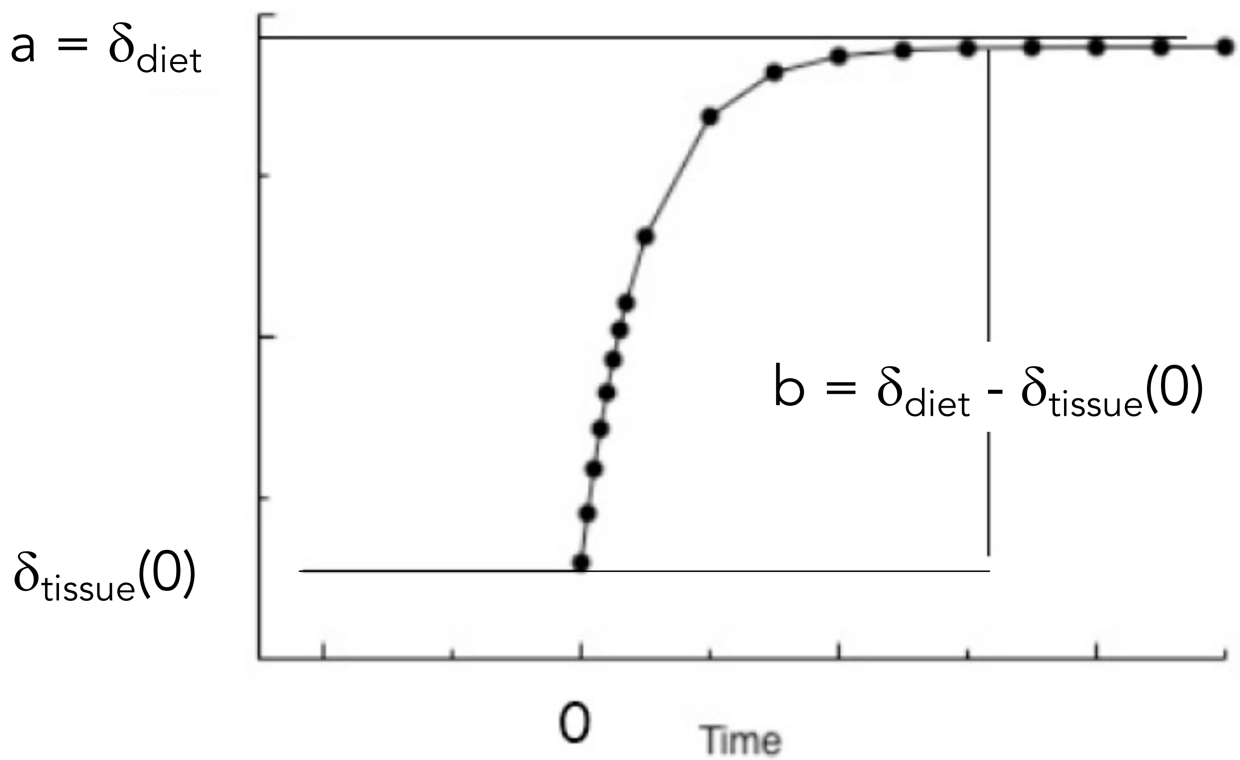

What About Plants?


What About Bacteria?

Kinetics of Isotopic Incorporation

$$\delta_{tissue}(t) = \delta_{diet} - (\delta_{diet} - \delta_{tissue}(0))e^{-rt}$$

$$\delta_{tissue}(t) = a - be^{-rt}$$



Diet change at time zero from $\delta_{tissue}(0)$ to δ_{diet}

Kinetics of Isotopic Incorporation

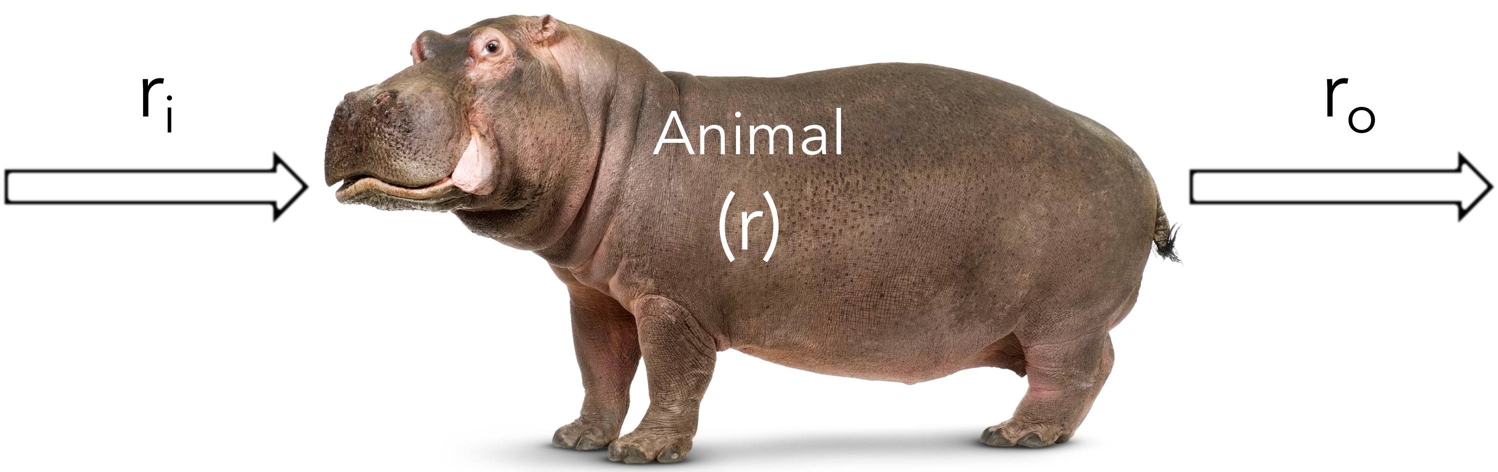
$$\delta_{tissue}(t) = a - be^{-rt}$$

$r = r_i$ = fractional rate of isotopic incorporation

flux into the pool / size of the pool

If animals are at steady state, then $r = r_i = r_0$

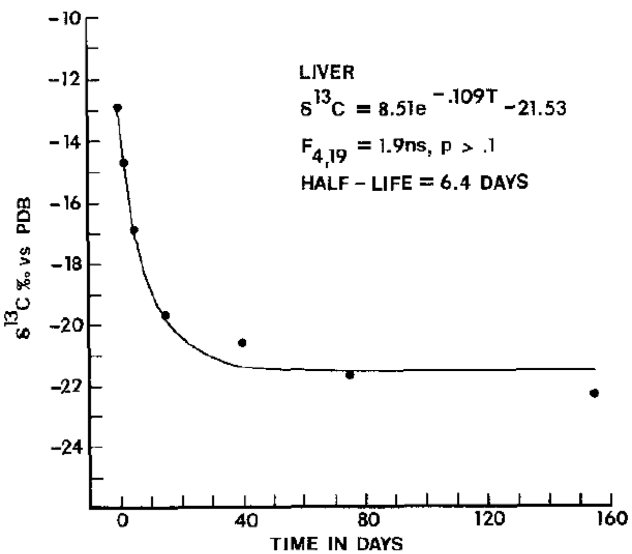
If animals are growing, then $r = r_{growth} + r_{metabolism}$

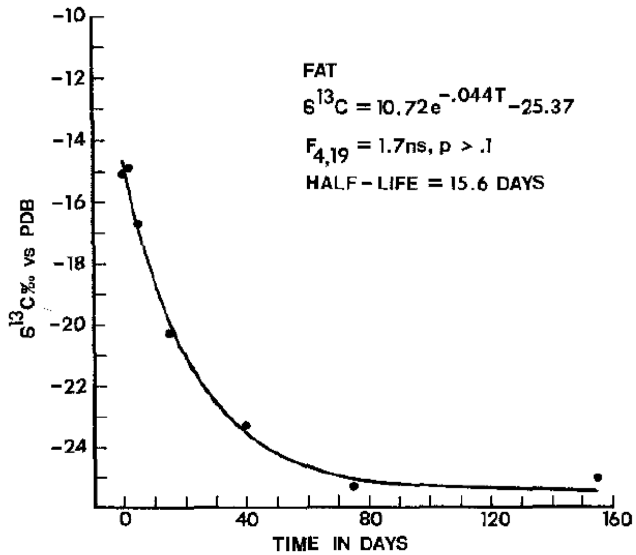


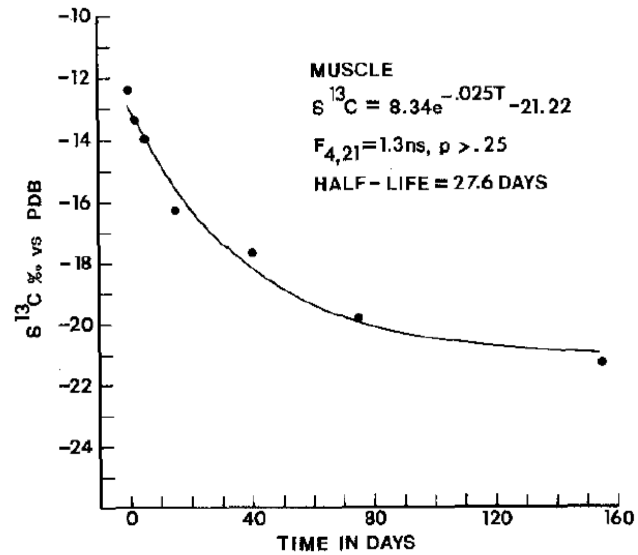
"Half-Life"

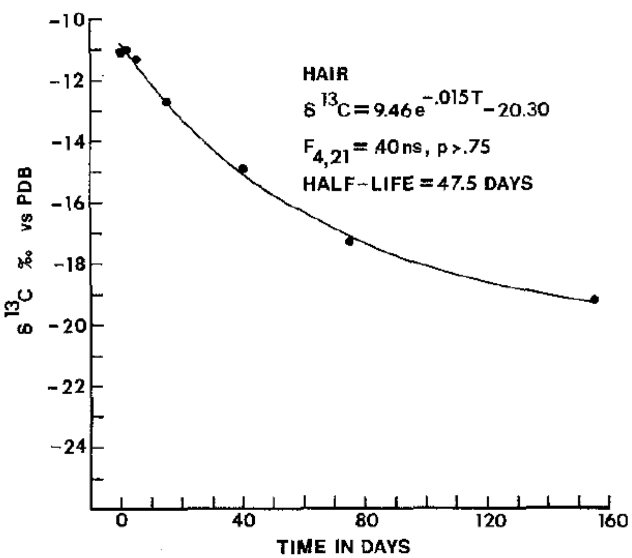
$t_{1/2} = Ln(2)/r$

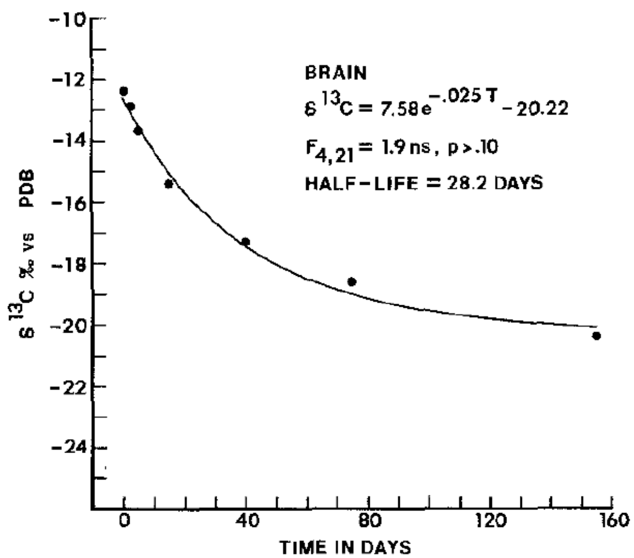
Isotopic Incorporation Origins











Meriones unguienlatus

Tieszen et al. 1983

Different Tissues Have Different Incorporation Rates

Cortunix japonicus

	1/r	Half-Life (days)
Plasma or Liver	3.7	2.5
Whole Blood	15.9	11.1
Muscle	17.6	12.2
Bone Collagen	250	173.3

The isotopic composition of liver tells us what the bird ate over the past ~10 days; muscle over the past ~60 days.

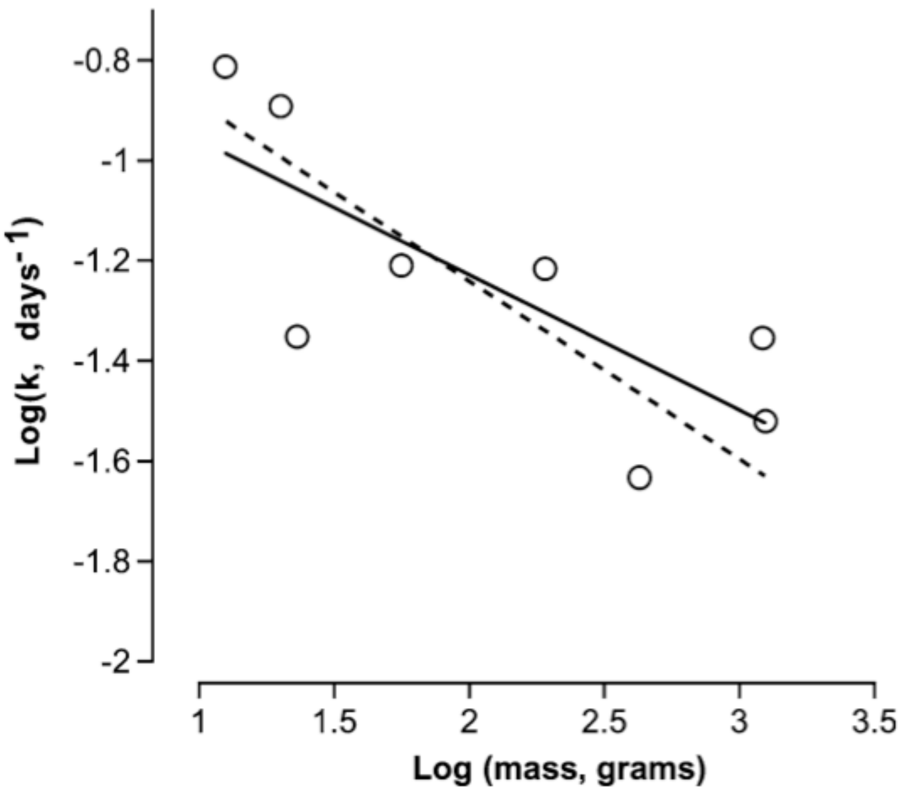
It's useful to analyze more than one tissue!
(plasma proteins versus red blood cells or muscle versus bone collagen)

Hobson and Clark 1992

Isotopic Incorporation Scales with Body Size

If r = flux/pool, allows us to make an allometric prediction:

Pool (A) = amount of element in an animal is a function of its mass
If we know A, then we can estimate F (flux)
$F = \text{flux} \propto \text{Mass}^{0.75}$
Thus $r = F/A \propto \text{Mass}^{0.75} / \text{Mass}$
$r = F/A \propto \text{Mass}^{-0.25}$



From warblers (10g) to ducks (1100g): exponent of relationship does not differ from -0.25 for whole blood in birds.

Isotopic Incorporation is faster in smaller animals than in large beasts.
(BUT WE NEED MORE DATA!)

Carleton and Martinez del Rio 2005

Isotopic Half Life Scales with Body Mass$^{-0.25}$

In big animals, even tissues that turnover relatively fast (e.g., blood) integrate ecological inputs over a long time periods.

For example, the half life of carbon in the blood plasma of a
~10g warbler should be ~10 days
~100kg ostrich should be ~90 days.

VS

Does Isotopic Incorporation Scale with Metabolic Rate?

…"turnover rates of carbon isotopes are related to metabolic rate."
(Voigt et al. 2003)

"These turnover rates were low compared to the information available for birds and eutherian mammals, and probably relate to the typically low metabolic rates of marsupials." (Klassen et al. 2004)

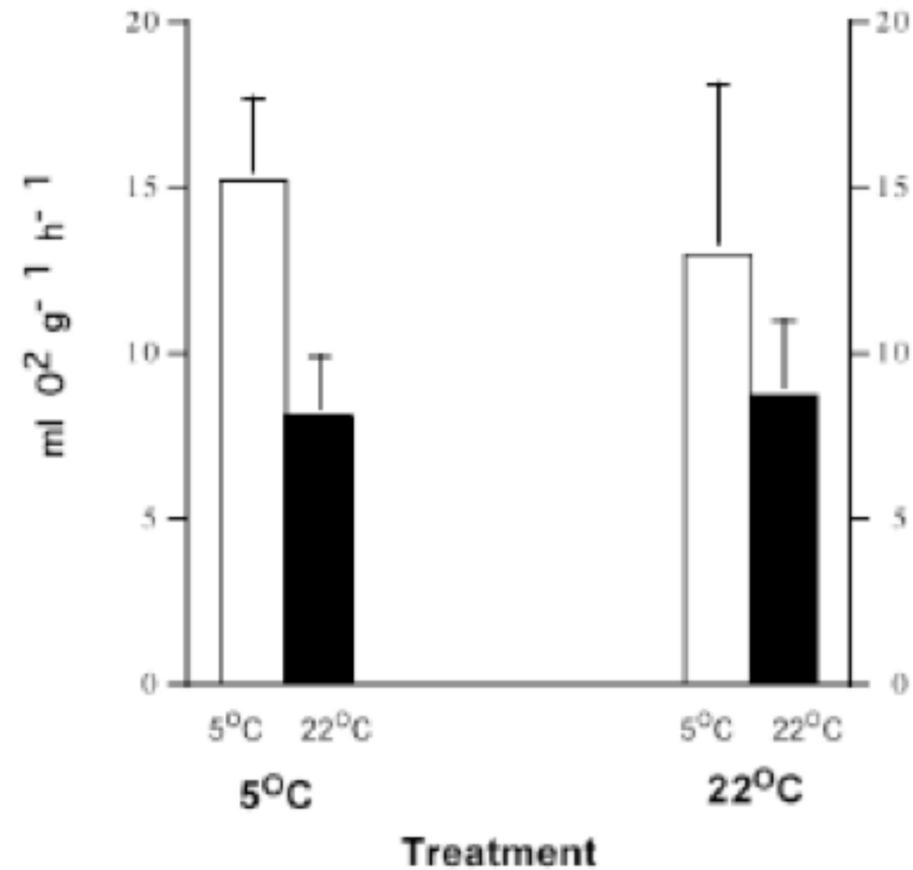
Isotopic Incorporation Rate ≈ Metabolic Rate?

60 days on a C_3 (wheat) diet
($\delta^{13}C$ = -25.5‰, $\delta^{15}N$ = 4.3‰)

↓

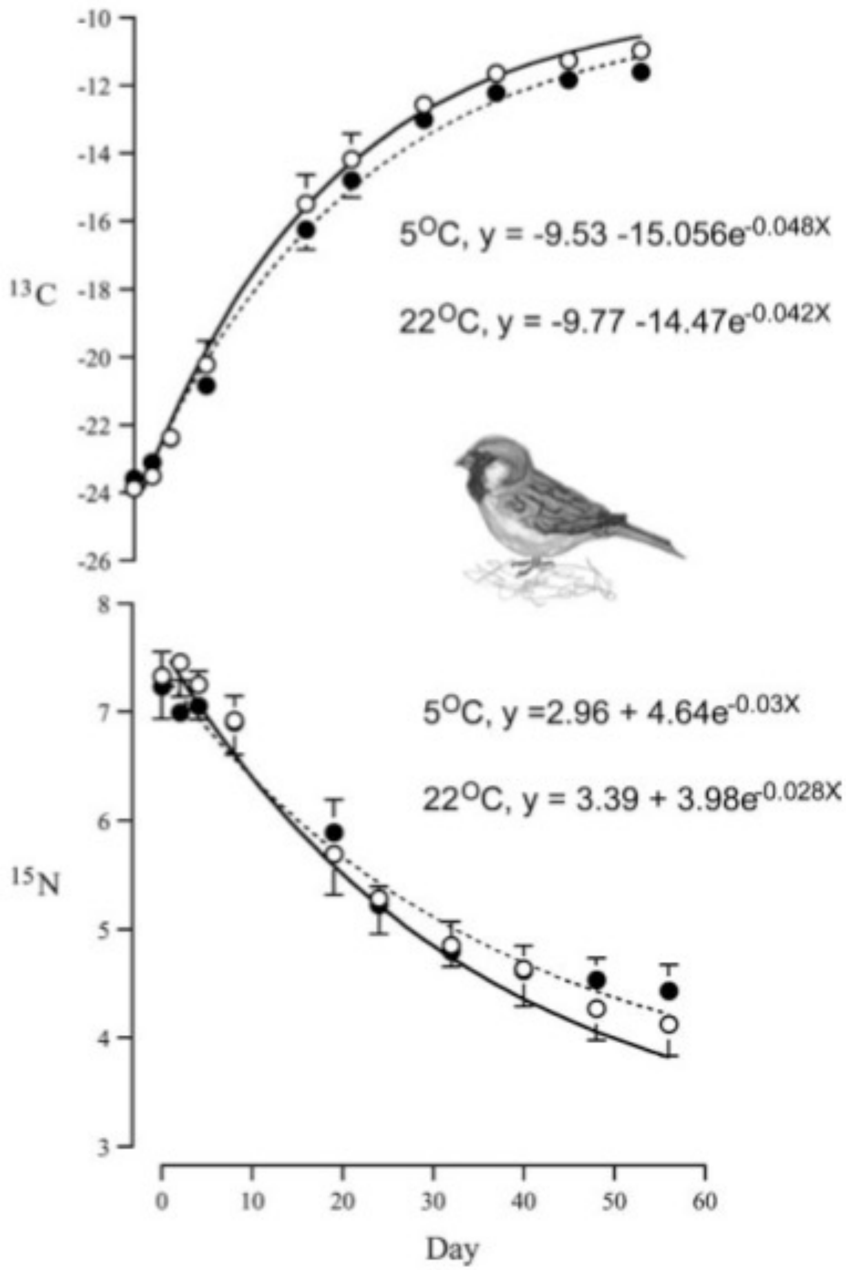
60 days on a C_4 (corn) diet
($\delta^{13}C$ = -11.5‰, $\delta^{15}N$ = 1.5‰)

House Sparrow Experiment:
2 Treatments; 5°C and 21°C
(2X change in metabolic rate)



Carleton and Martinez del Rio 2005

House Sparrow Results

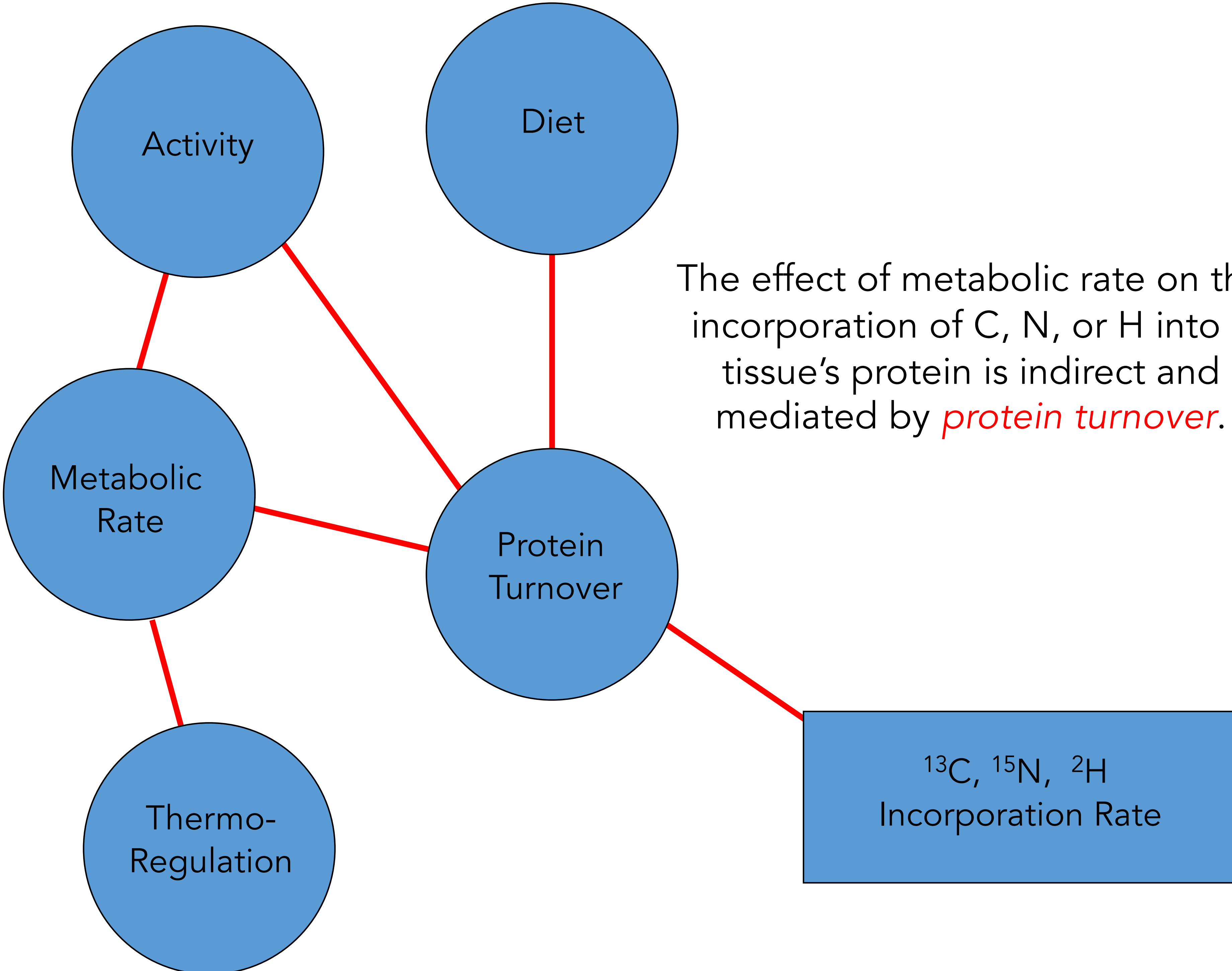


No significant effect of a cold-induced increase in metabolism on the rate of C and N incorporation.

We can uncouple the relationship between metabolic rate (MR) and incorporation rate (r)

What factor(s) (besides body mass) drive isotopic incorporation?

Carleton and Martinez del Rio 2005



The effect of metabolic rate on the incorporation of C, N, or H into a tissue's protein is indirect and mediated by *protein turnover*.

Carleton and Martinez del Rio 2005