Avian Migration

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- What is migration?
- History of avian migration
- Evolution of migration
- Navigation, how do birds migrate
- Energetic demands of migration
- Measuring migration behaviors
- Why do we care about migration?

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Migration

- The periodic passage of groups of animals from one region to another generally for feeding or breeding
- Distinct from other kinds of animal movement because
  - Seasonal
  - Predictable
  - Repeatable
- 50% of birds breeding in temperate/arctic North America winter in the tropics or subtropics (Neotropical Migrants)

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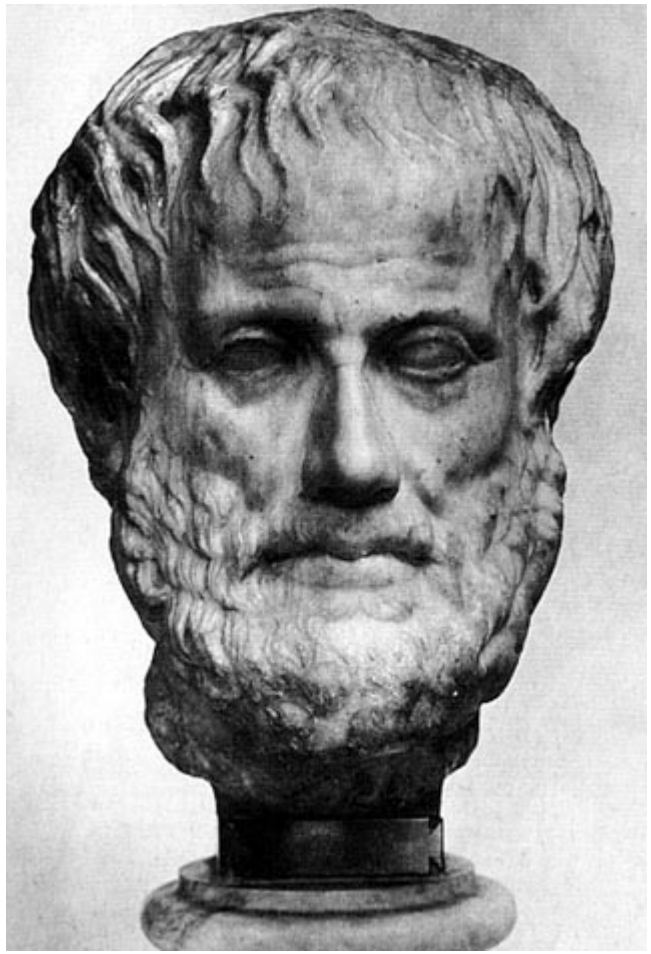
History of Avian Migration

- First records of migration over 3000yrs ago
- Aristotle noted seasonal passing of birds
  - Did not understand why
  - Promoted transmutation & hibernation
- References in the Bible
  - Doth the hawk fly by Thy wisdom and stretch her wings toward the south (Job 39:26)
- Historical Myth
  - Mediterranean – small birds congregate to ride larger birds to Africa
  - Native Americans – hummingbirds ride the backs of geese



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Evolution of Migration

Evolution of Migration

Why migrate?

- Why leave winter habitats to breed?
- Why leave breeding habitats to winter?

BOTH EXAMPLES MUST INCREASE FITNESS

Evolution of Migration

- Fossil evidence suggests that birds arose in the tropics

Why Migrate?

- Why leave the tropics to breed?

Why Migrate?

- Why leave the tropics to breed?
  - High competition for food and breeding territories
  - Temperate productivity
  - Extreme nest predation

Low Reproductive Success

Why Migrate?

- Why leave temperate habitats to winter?

Why Migrate?

- Why leave temperate habitats to winter?
  - Extreme weather conditions
  - Limited food availability

Low Adult Survival

Survival Rates

Residents

Song Sparrow	41%
Chickadees	40%

Short-distance Migrants

Prairie Warbler	64%
Yellow Warbler	53%
C. Yellowthroat	54%

Partial Migrants

Blackbirds	51%

Long-distance Migrants

N. Waterthrush	73%
Ovenbird	85%

Tropical Residents

Average Values	80-90%

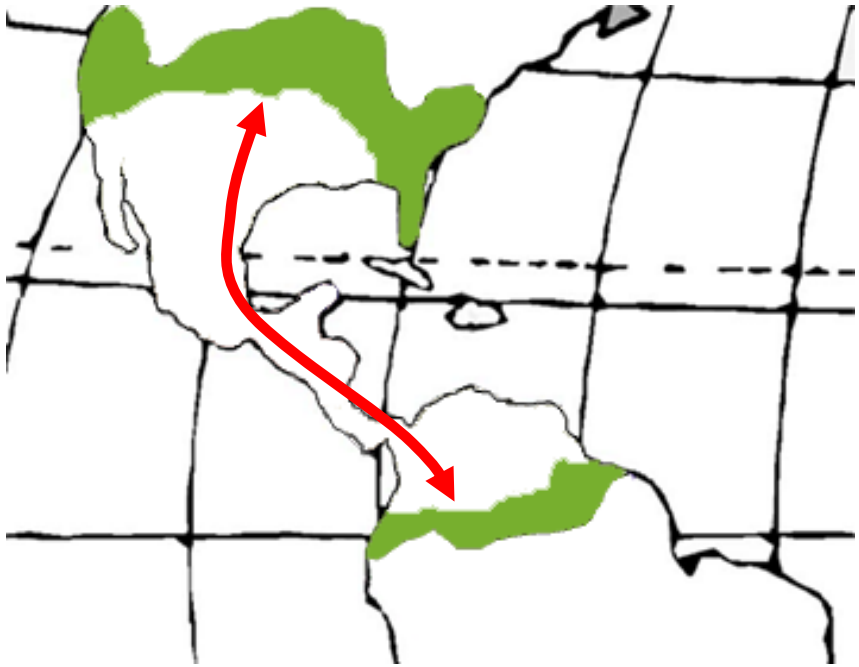
Evolution of Migration

- Thus, migration likely arose in low latitude residents that moved to exploit seasonal food abundance and limited population densities

- Current migratory paths have probably evolved since the last glaciation in response to retreating glaciers

Patterns of Migration

- Latitudinal Migration – Temperate ⟷ Tropics
  - Most common



Patterns of Migration

- Latitudinal Migration – Temperate ⟷ Tropics
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- Longitudinal Migration – Inland ⟷ Coast
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  - Most common
- Longitudinal Migration – Inland ⟷ Coast
  - Waders and waterfowl
- Altitudinal Migration – High ⟷ Low
  - Common in the tropics or costal areas
- Weather Migration – Dry → Wet
  - Common in subtropics

Types of Migration

- **Complete Migration** – when the entirety of the population migrates
- **Partial Migration** – some of the population migrates, some are resident
- **Long-distance Migration** – movements of vast distances, usually between continents
- **Short-distance Migration** – movements within a continent

Types of Migration

- **Differential Migration** – different portions of the population migrate different distances (e.g. sex, age)

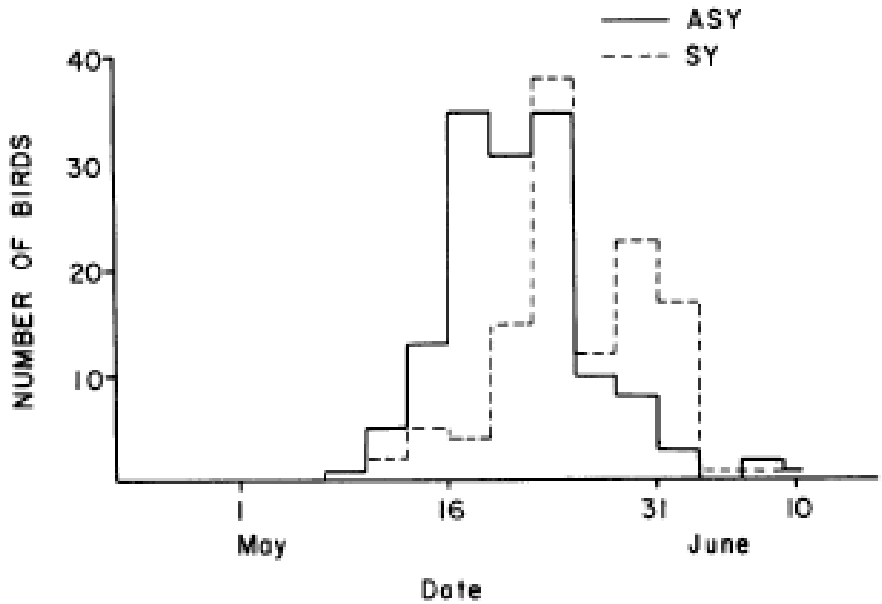


Fig. 3. Numbers of second-year (SY) and after-second-year (ASY) male American Redstarts captured at Prince Edward Point, 1976–1980 (3-day totals).

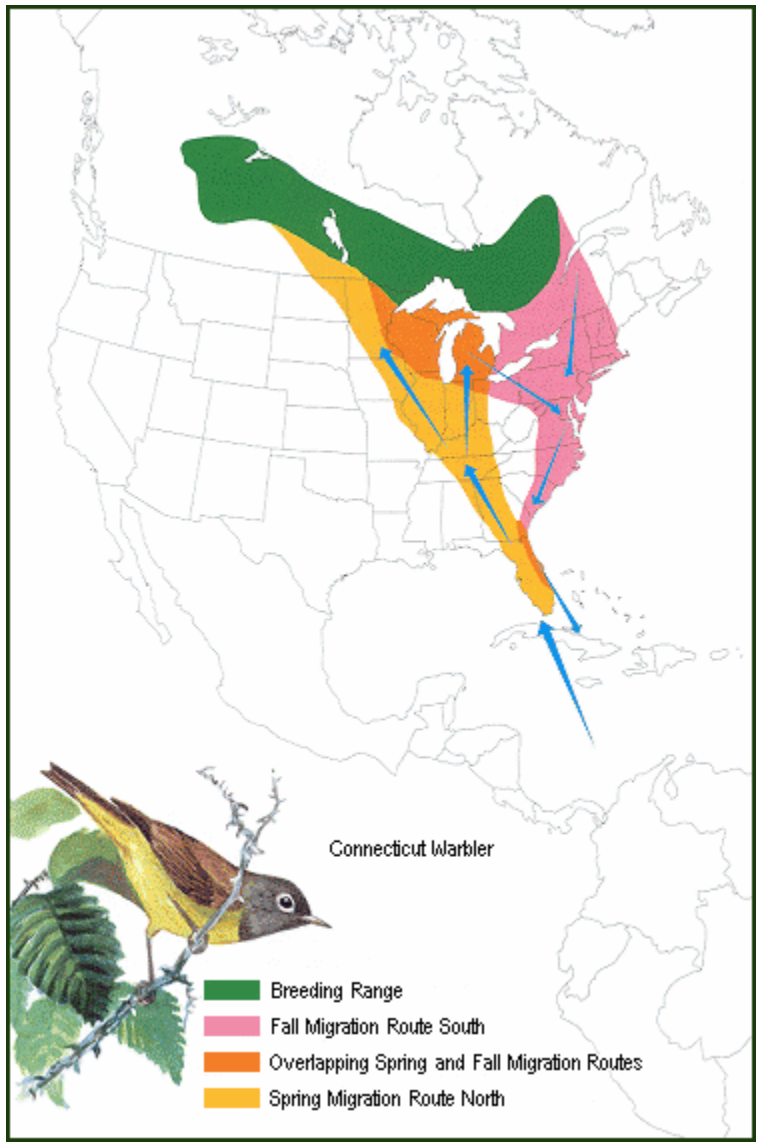
Francis and Cooke 1986

Types of Migration

- **Irruptive Migration** – migration only occurs in some years, and migration distances vary among years (e.g. predators and seedeaters)

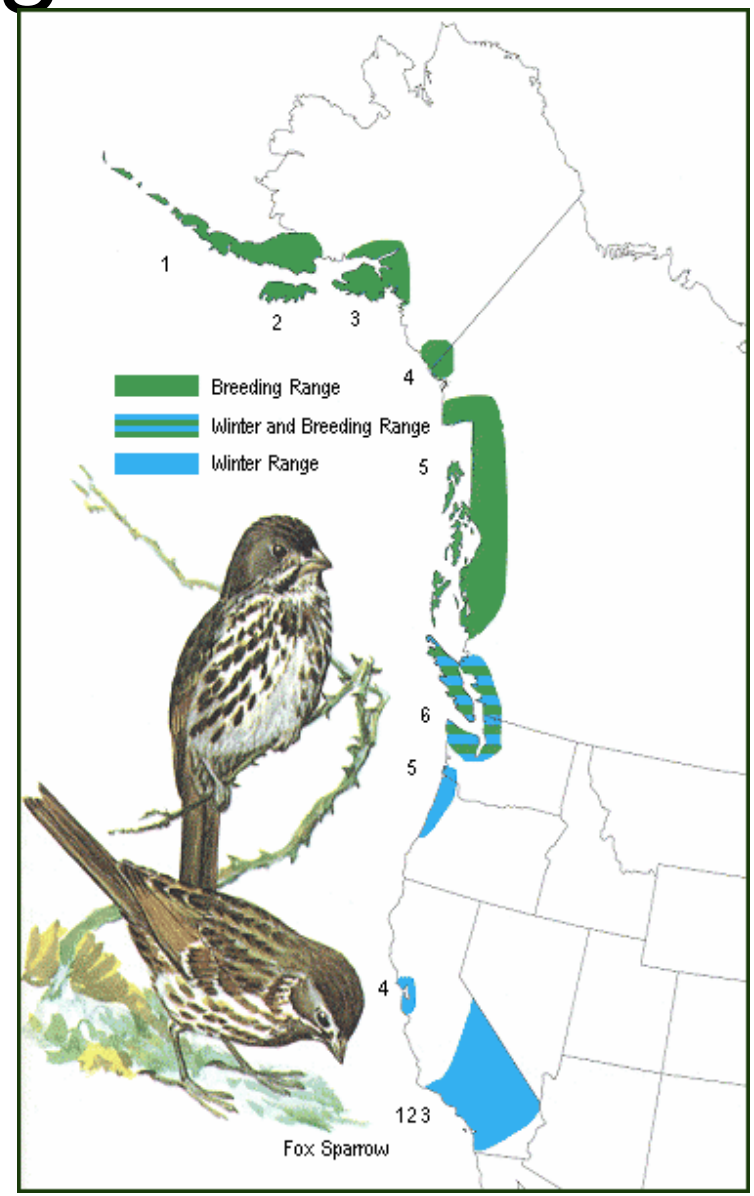
Types of Migration

- **Loop Migration** – migration where paths differ between northern and southern migrations, characteristic of many species.



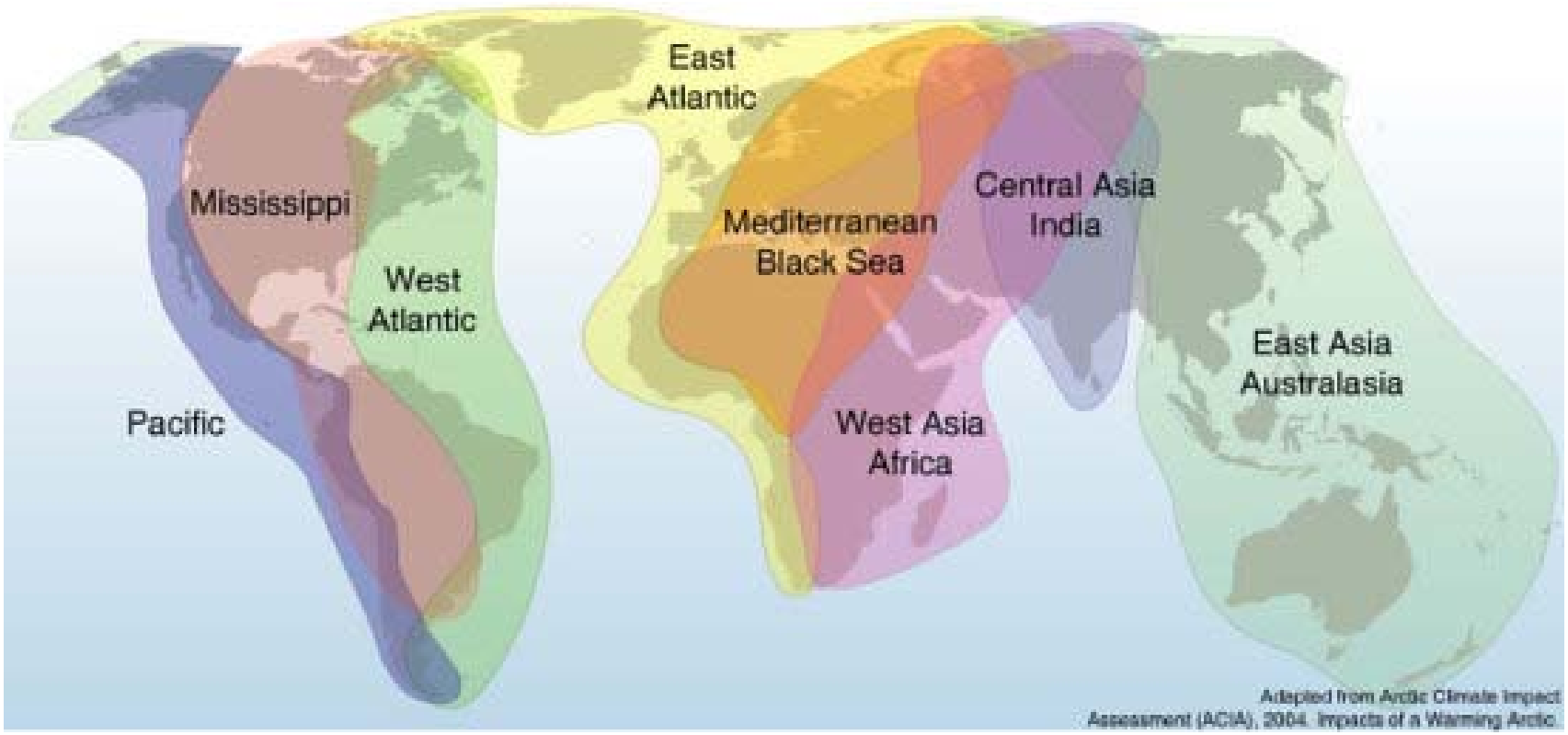
Types of Migration

- **Leap-frog Migration** – migration where northern populations winter further south than southern populations



Migratory Routes

- Most long distance migrants follow traditional migratory routes



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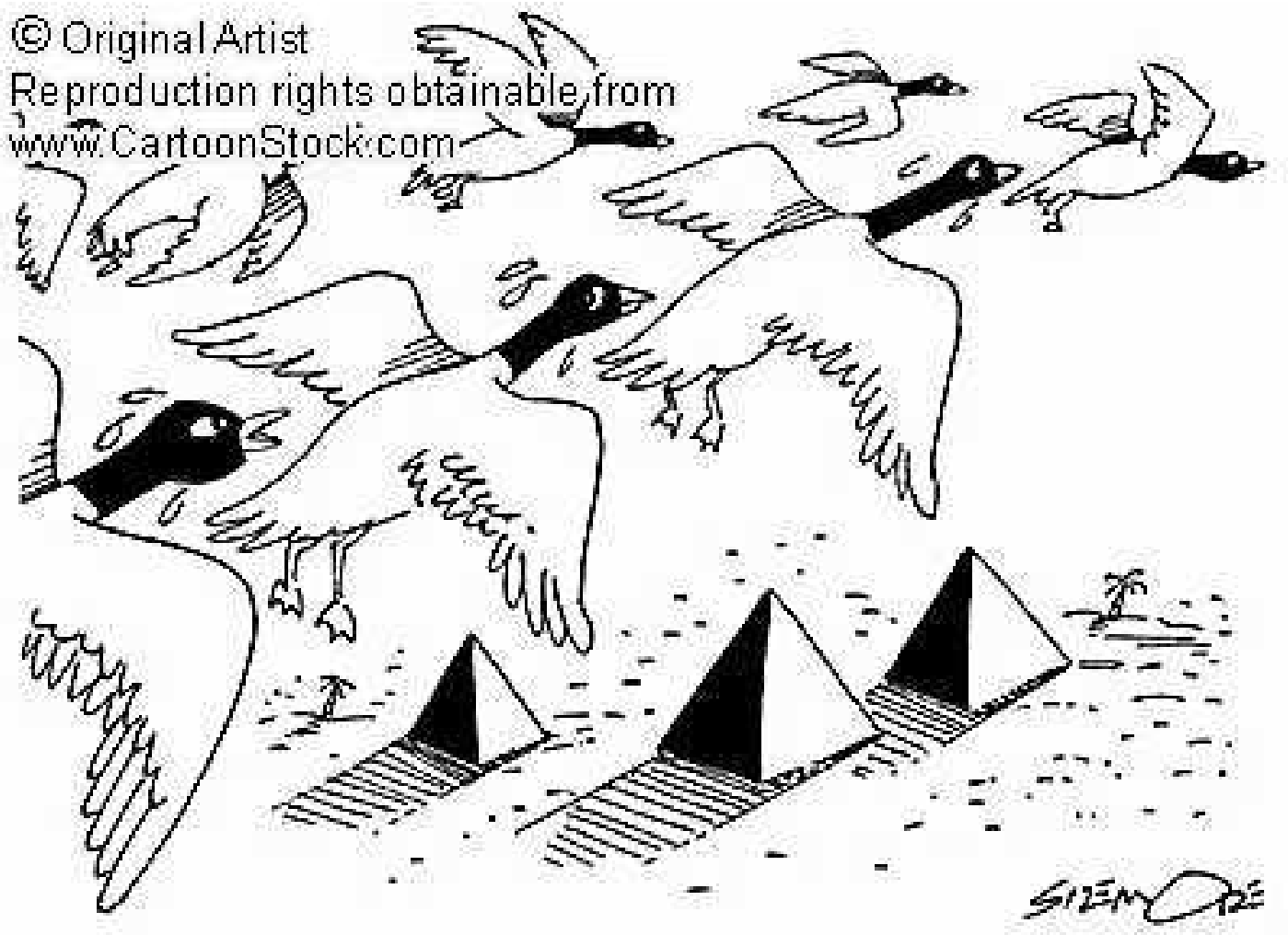
Orientation/Navigation Cues



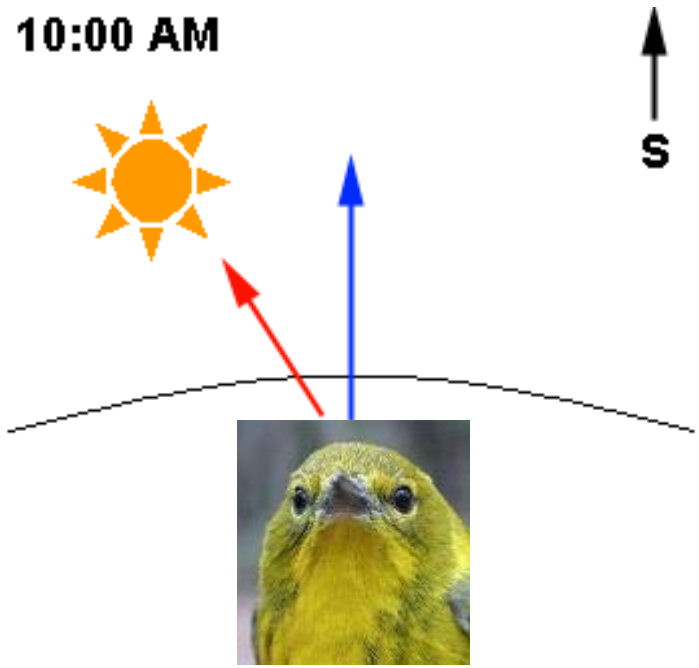
"Well, dammnit, I say he should stop and ask someone!"

Orientation/Navigation Cues

- **Visual Orientation** – use landmarks, common for diurnal migrants but not nocturnal migrants

Orientation/Navigation Cues

- **Sun Compass** – birds use the position of the sun to provide information on migratory direction

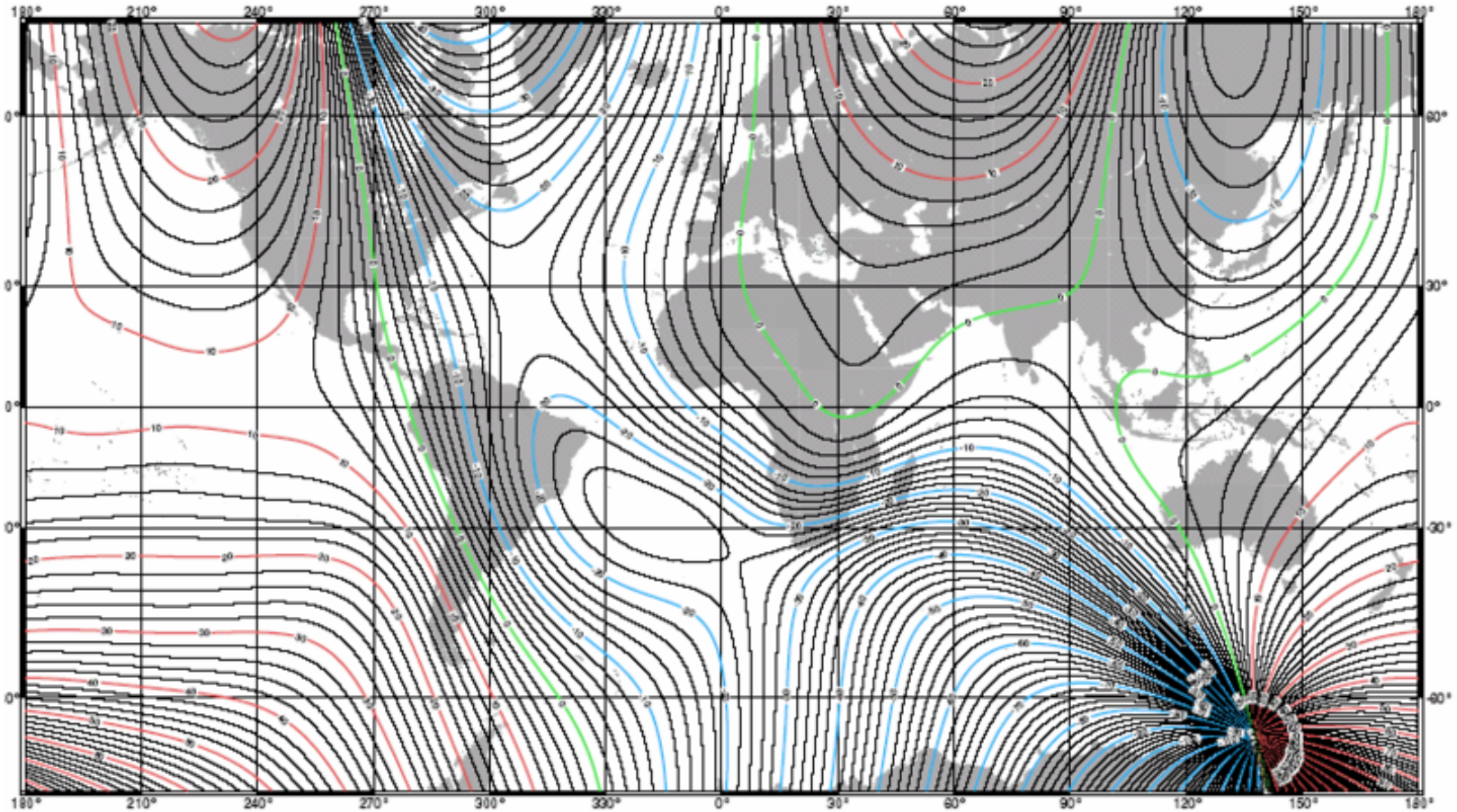


Orientation/Navigation Cues

- **Celestial Navigation** – nocturnal migrants use star position for orientation

Orientation/Navigation Cues

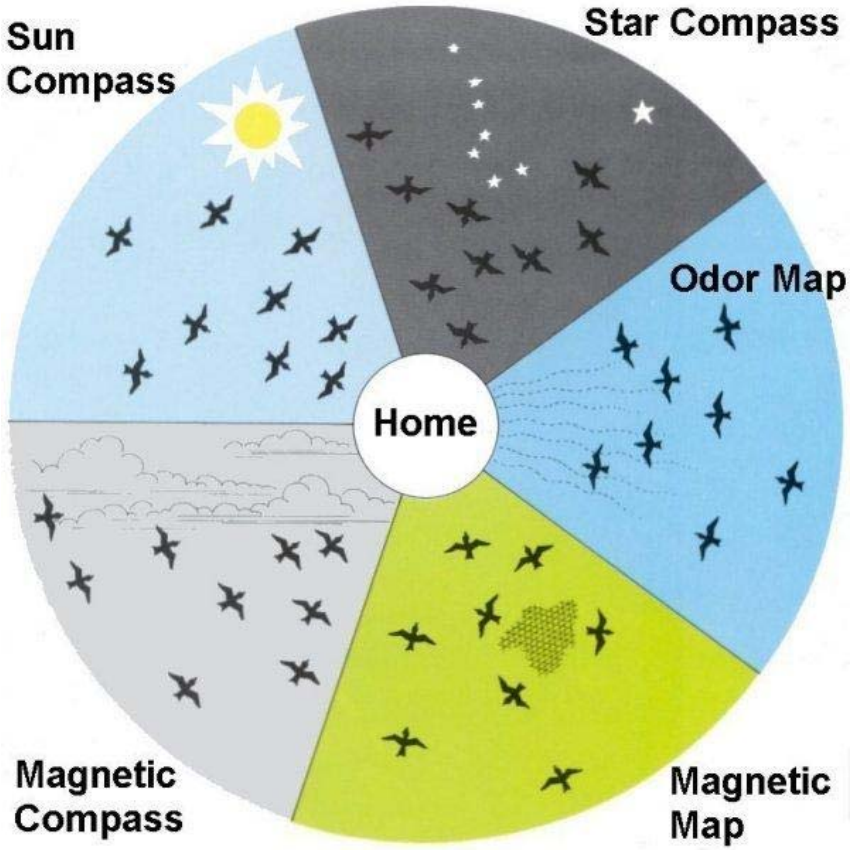
- **Geomagnetism** – use of the earth's magnetic field for orientation (map or compass)



Orientation/Navigation Cues

- **Olfactory map** – use of regional and local smells to navigate

Orientation/Navigation Cues



Ultimately proper orientation and navigation involves a combination of cues as well as experience and learning

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Energetic Demands of Migration

- Flying requires copious amounts of energy

- Birds must carry energy reserves or stop to refuel

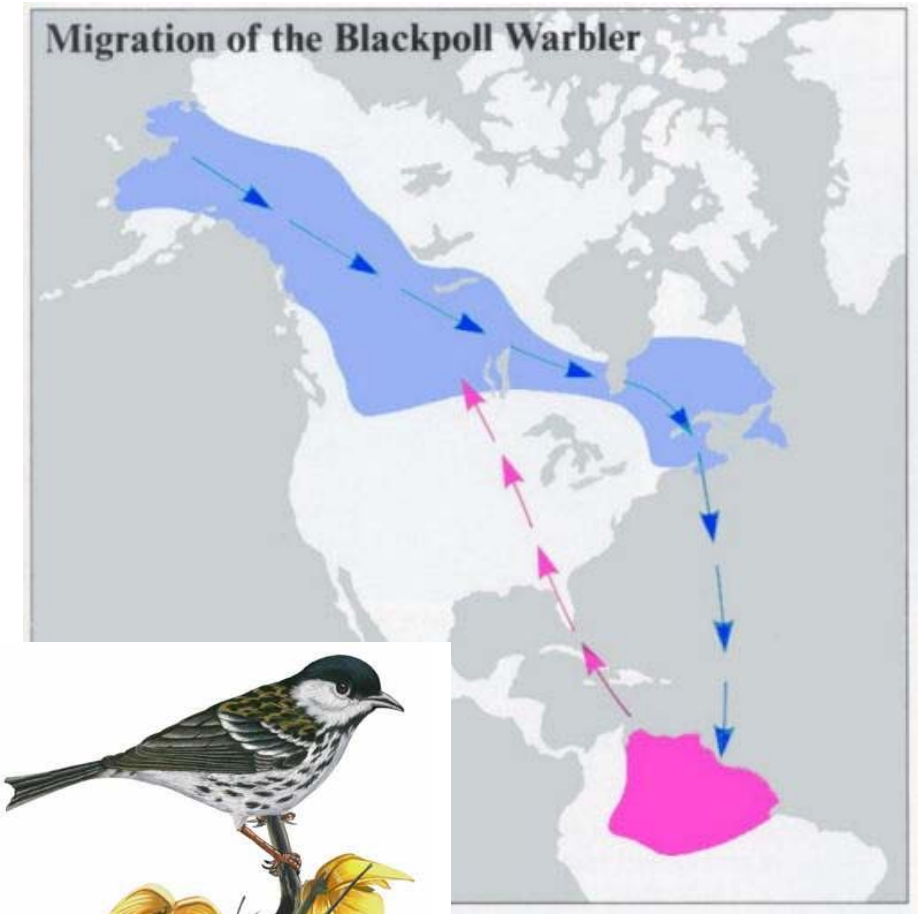
Energetic Demands of Migration

- Fat is the fuel of migration – 2X the energy of carbohydrates or proteins
- Birds store fat around organs to distribute weight
- Fat typically accounts for <5% of mass, but in short-distance migrants >25% and long-distance migrants may double body weight

Energetic Demands of Migration

- Long-distance migrants have evolved efficiency (the hybrid cars of the bird world)

- Blackpoll warblers are 2X more efficient than typical passerines



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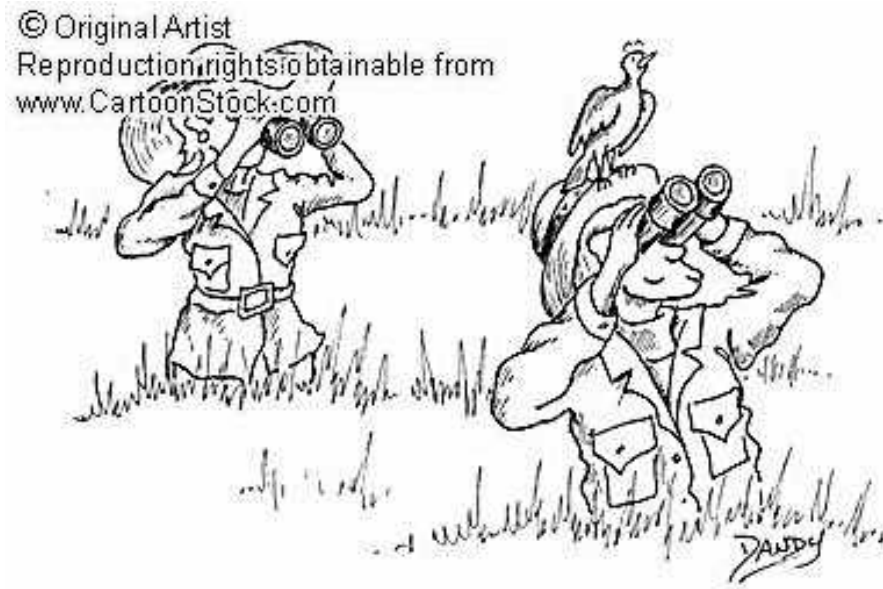
Quantifying Migration Behaviors and Routes

- Observations
- Specimen collections
- Emlen Funnel
- Banding
- Radio Tracking
- Radar
- Isotopes

Observations

- Daytime counts of foraging migrants
- Moon-watch and aural counts of flying migrants
- 1880's-1920's documentation of largest migration routes, stopover locations, and timing
- Still common but limited ability to identify individuals or populations although technological advances have improved data



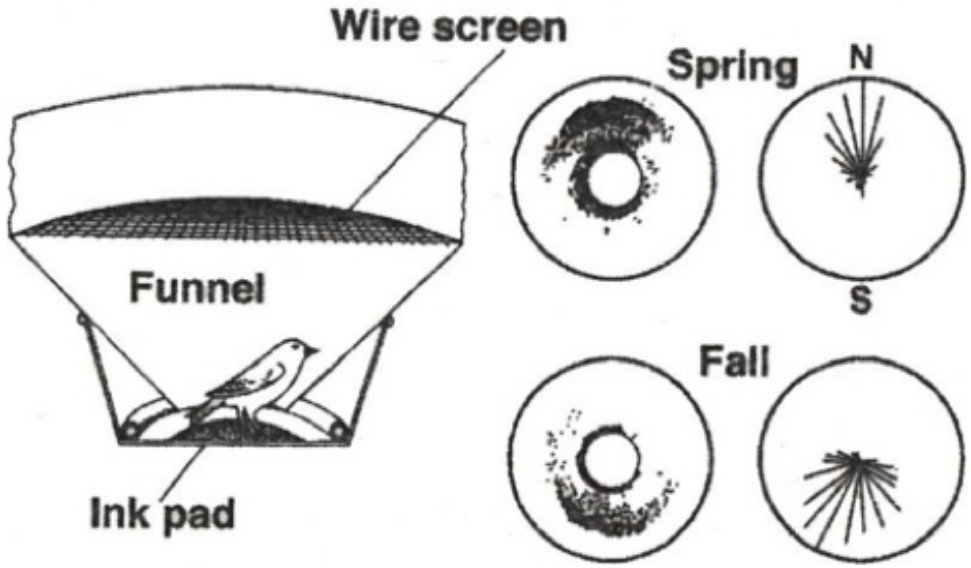
Specimen Collections

- Provides information on
  - Species, morphology, physiology, timing, location
- No behavioral information and limited ability to identify populations (new focus on DNA)

Emlen Funnel

- Provides information on
  - zugenruhe (nocturnal restlessness during migration)

- Great behavioral information, but limited inference



Banding

- 1595 Henry IV's Peregrine Falcons was lost in France and showed up 24hrs later in Malta, about 1350 miles away

- 1902 Paul Bartsch banded >100 black-crowned night herons with bands inscribed "Return to Smithsonian Institution”

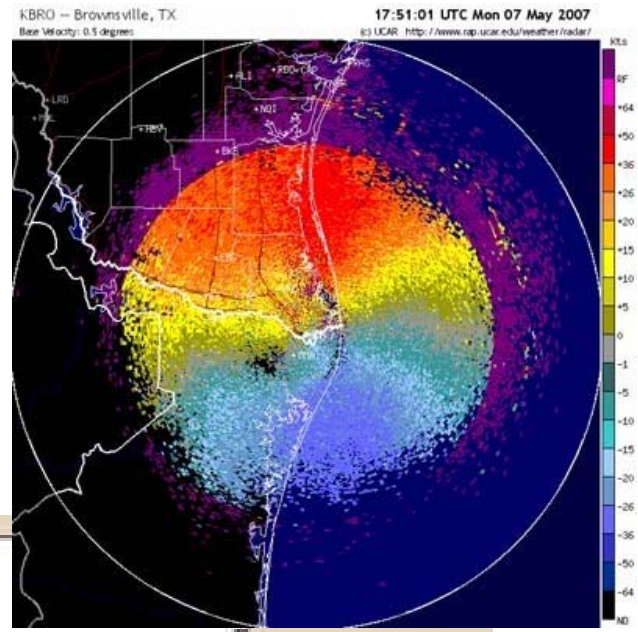
- 1920 Bureau of Biological Survey and the Canadian Wildlife Service began the North American banding program

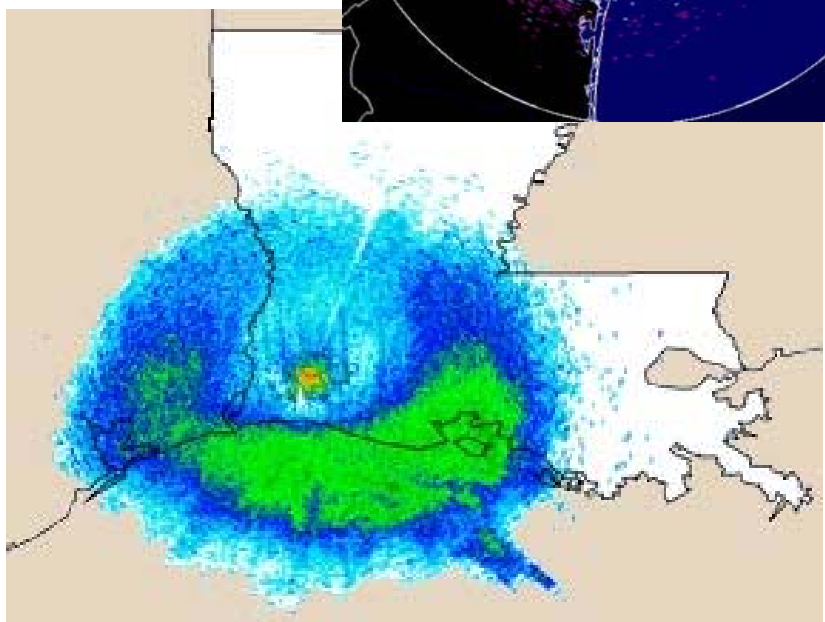
Banding

- Provides information on
  - Arrival and departure dates
  - Stopover duration
  - Effects of weather
  - Migration rates
  - Site fidelity
- Effective for hunted species, but <1% of non-hunted birds are ever recaptured

Radar

- Provides information on
  - Numbers (rarely species)
  - Direction and speed
  - Precise dates and time
  - Heights of travel
  - Volume of birds
  - Migration routes (ocean, coastal, riparian)
- Limitations
  - Surface clutter
  - Doesn't identify individuals

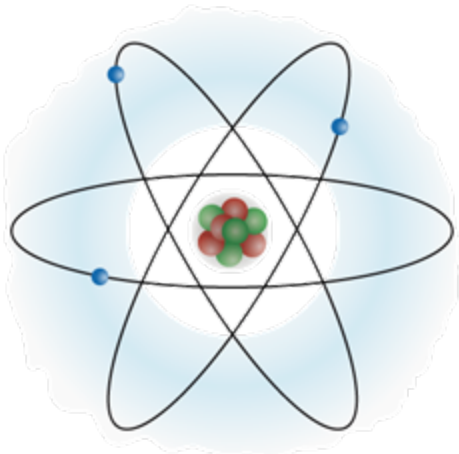




Radio Tracking

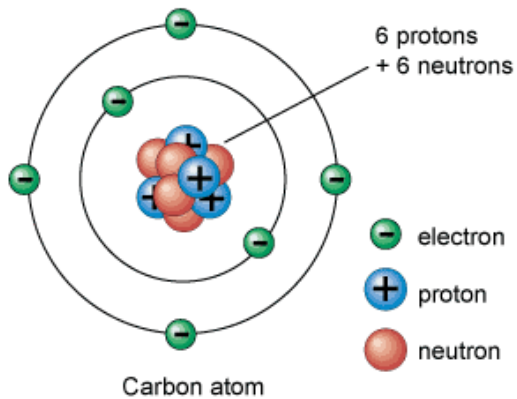
- Attach a small radio to a bird and follow with a receiver
- Great information on stopover duration, foraging behaviors, migration routes
- Limited by size of radio and transmission distance, and significantly reduces survival (GPS is the new frontier, but $$$$)

Stable Isotopes



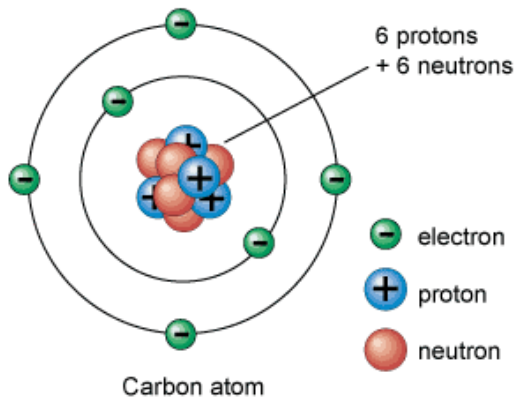
What is an isotope?

- Atoms with the same number of protons & electrons, but different number of neutrons:
  - ^{12}C: 6 protons + 6 neutrons: stable
  - ^{13}C: 6 protons + 7 neutrons: stable
  - ^{14}C: 6 protons + 8 neutrons: radioactive
- Mostly the same chemical properties, but….
  - They have slightly different weights so they behave slightly differently (this is the important point!)



Heavy isotopes occur less commonly in nature

Isotope	Mass	Abundance
n	1.008665	
H	1.007825	99.9844%
D	2.0140	0.0156
^{12}C	12.0000	98.89
^{13}C	13.003355	1.11
^{14}N	14.003074	99.64
^{15}N	15.000108	0.36
^{16}O	15.994915	99.763
^{17}O	16.999131	0.0375
^{18}O	17.999160	0.1995
^{32}S	31.972070	95.02
^{33}S	32.971456	0.75
^{34}S	33.967866	4.21
^{36}S	35.967080	0.02



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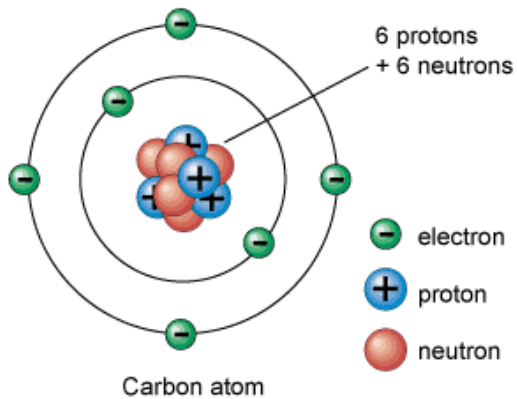
But the precise ratio is highly variable



13C/12C ≠ 13C/12C

Delta (δ)

- **$\delta^{13}C$ (‰) = [$^{13}C/^{12}C$ sample/ $^{13}C/^{12}C$ standard -1] x 1000**

- What does delta notation mean?
  - δ **>** 0: enriched in heavy isotope
  - δ **<** 0: enriched in light isotope (or depleted in heavy isotope)

Sources of Variation in Delta (δ)

- Environmental or Abiotic (H or O)
- Biological or Biotic (C or N)

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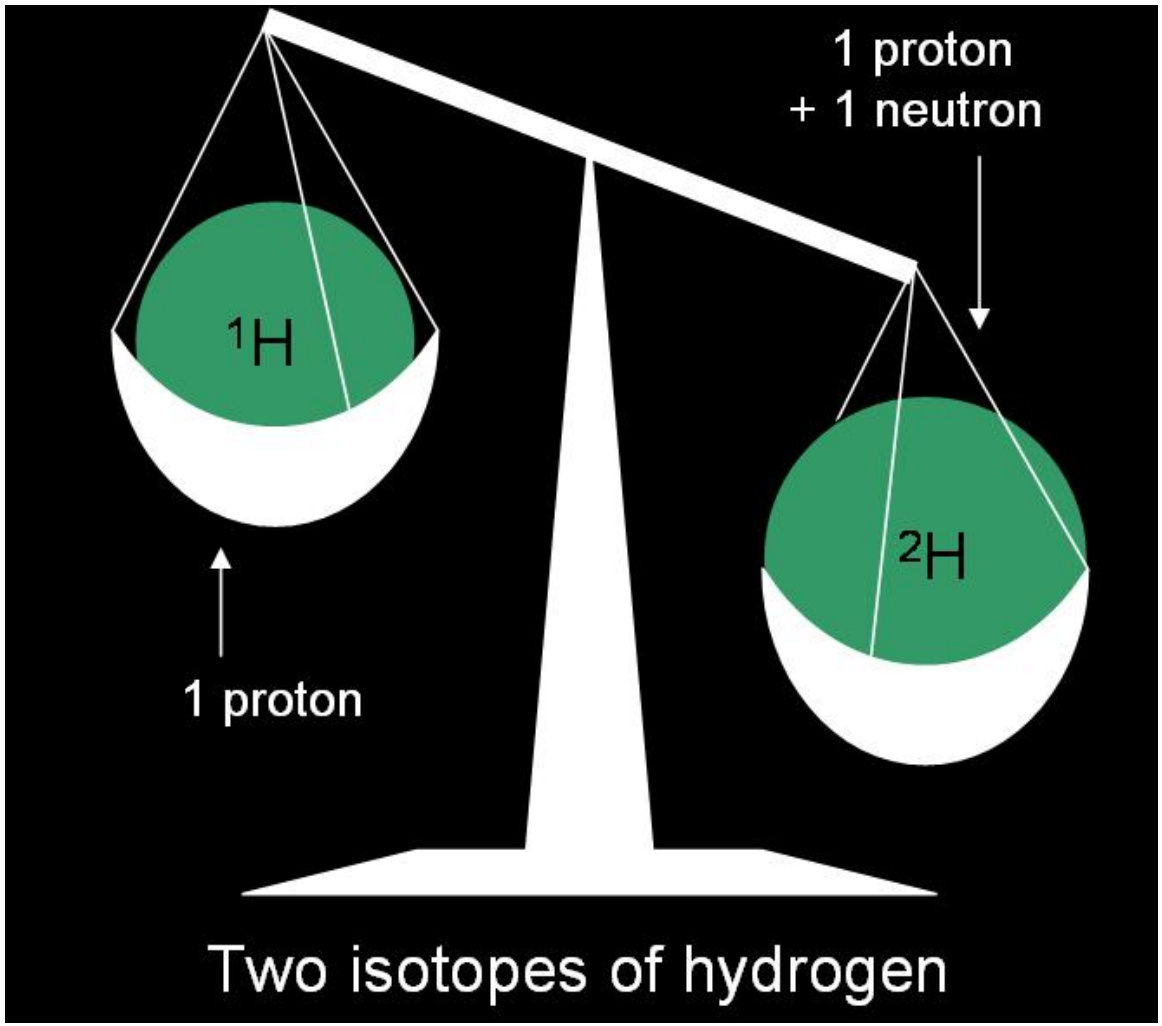
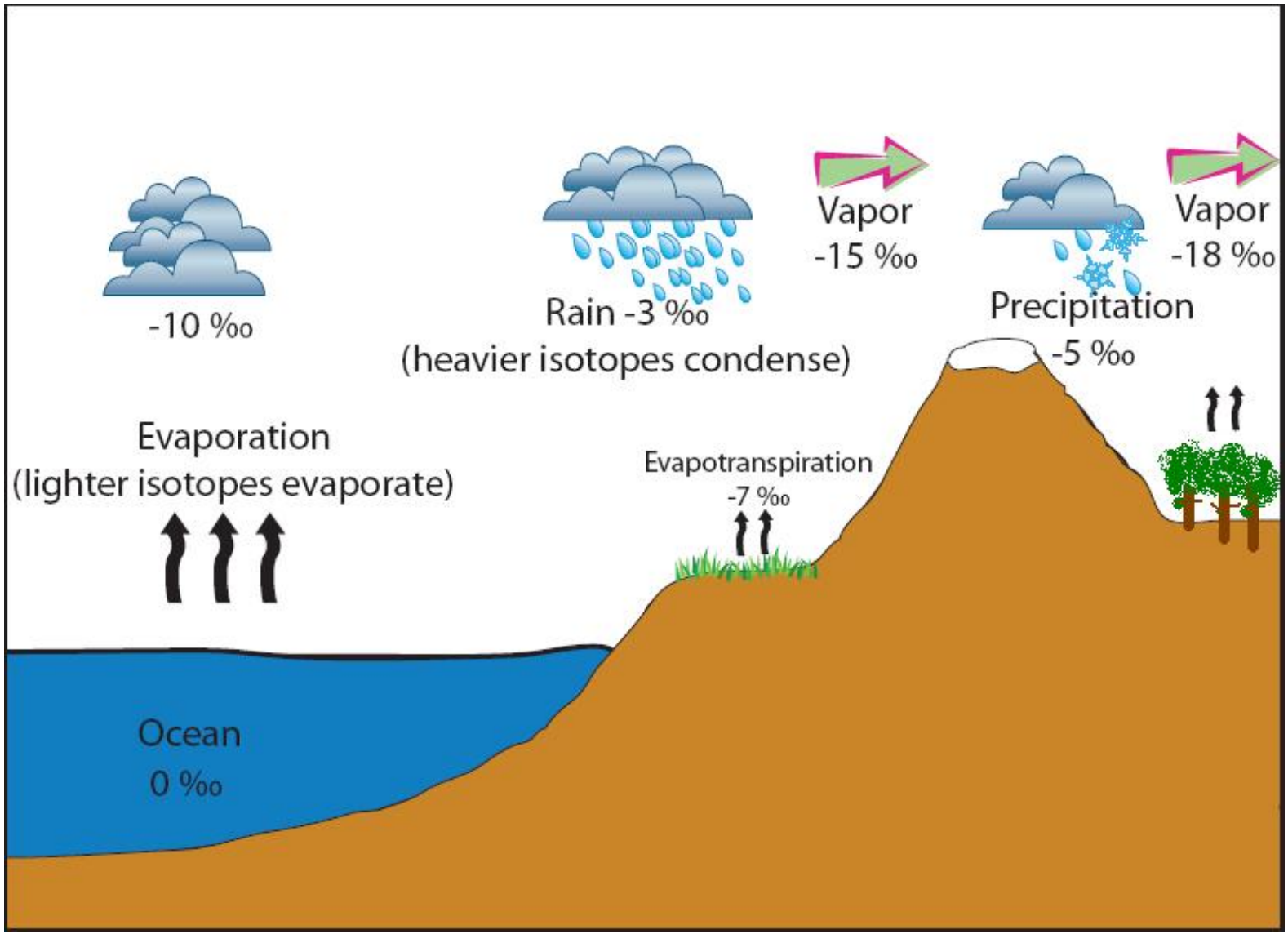
Environmental Variation in Delta (δ)



Environmental Variation in Delta (δ)

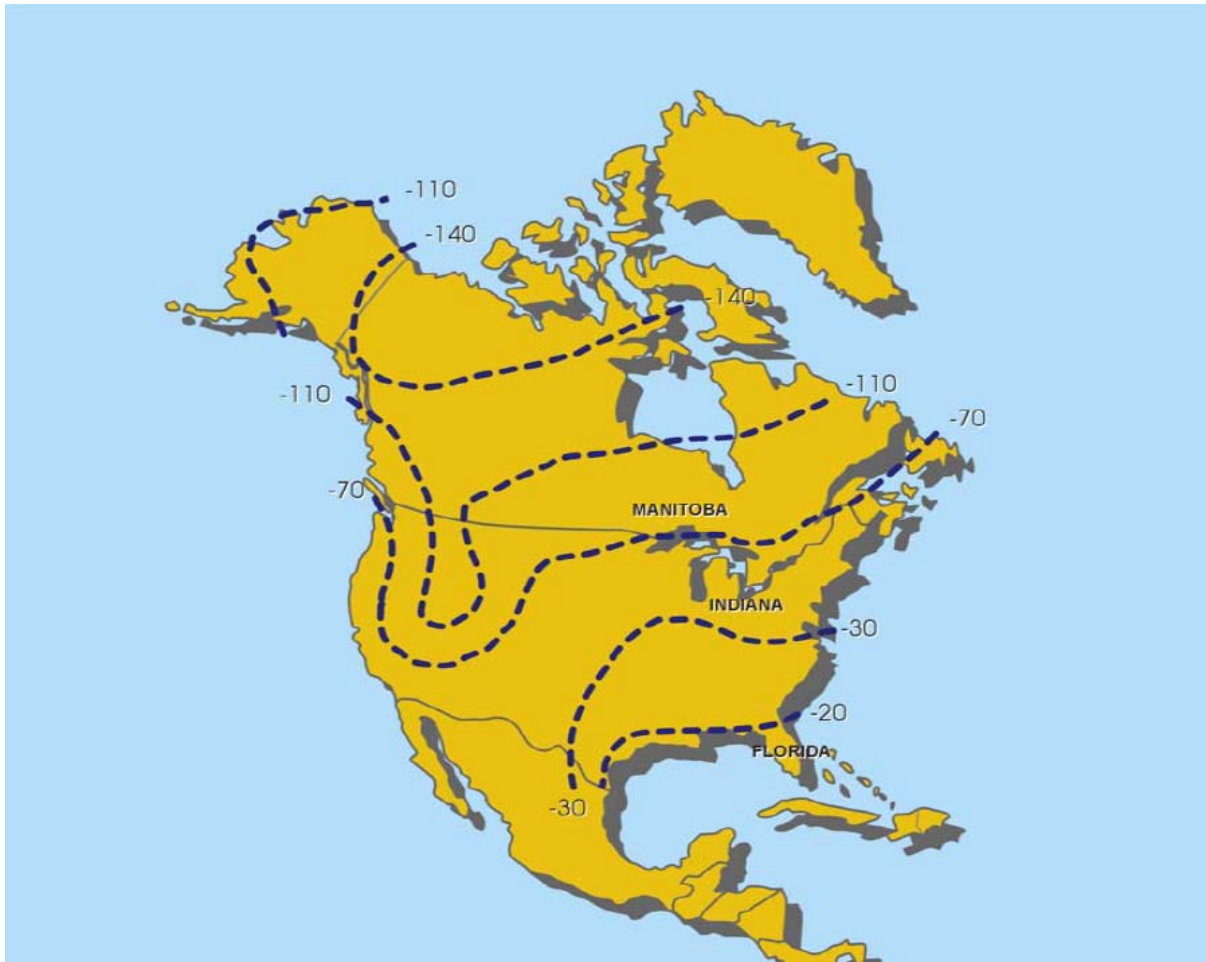


Environmental Variation in Delta (δ)

- Hydrogen Gradient
  - (δ) decreases (i.e. lighter) with increasing latitude
  - (δ) decreases (i.e. lighter) with increasing distance from the ocean

Environmental Variation in Delta (δ)

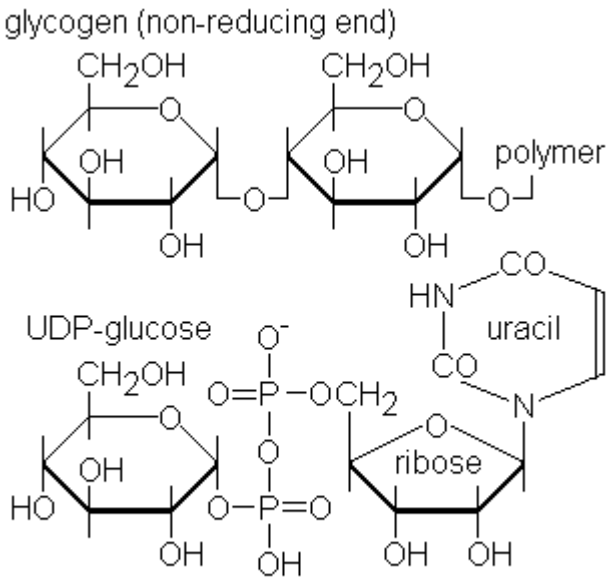
- Hydrogen Gradient



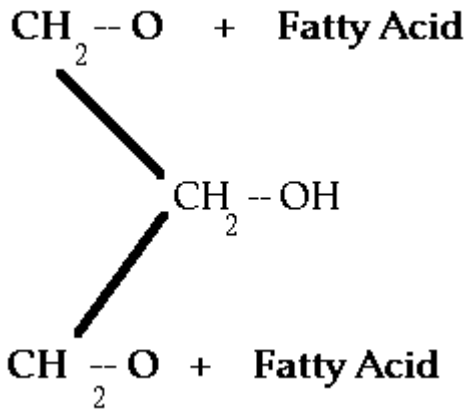
You are what you eat!

You are what you eat !

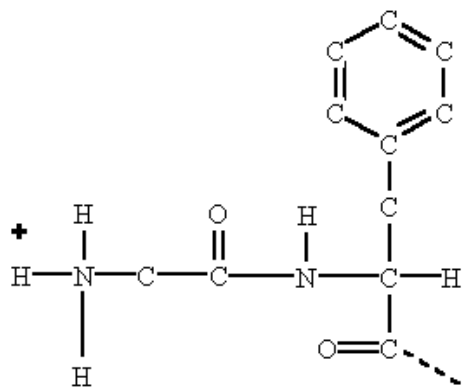
Carbohydrate



Lipid



Protein



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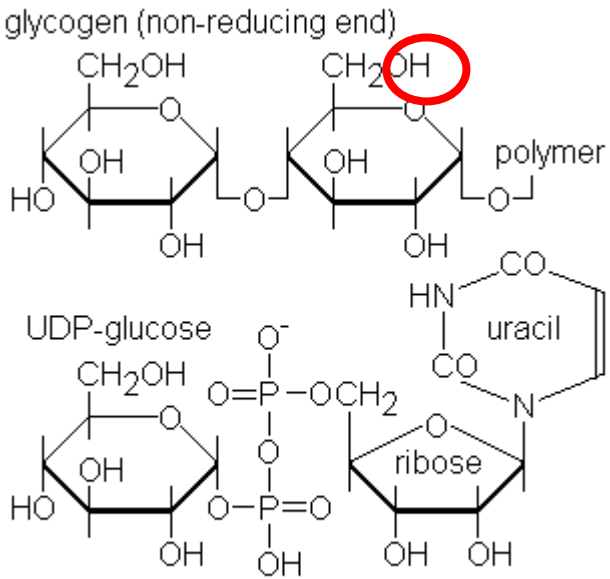

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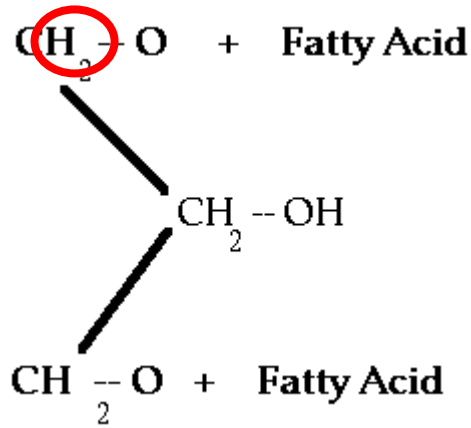
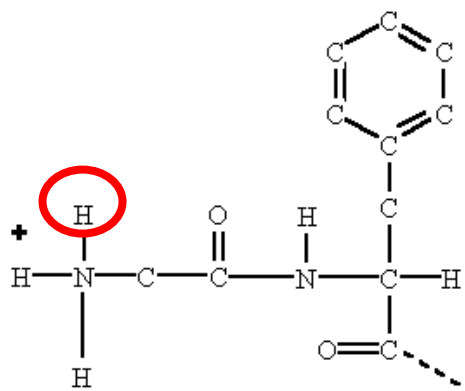


Protein



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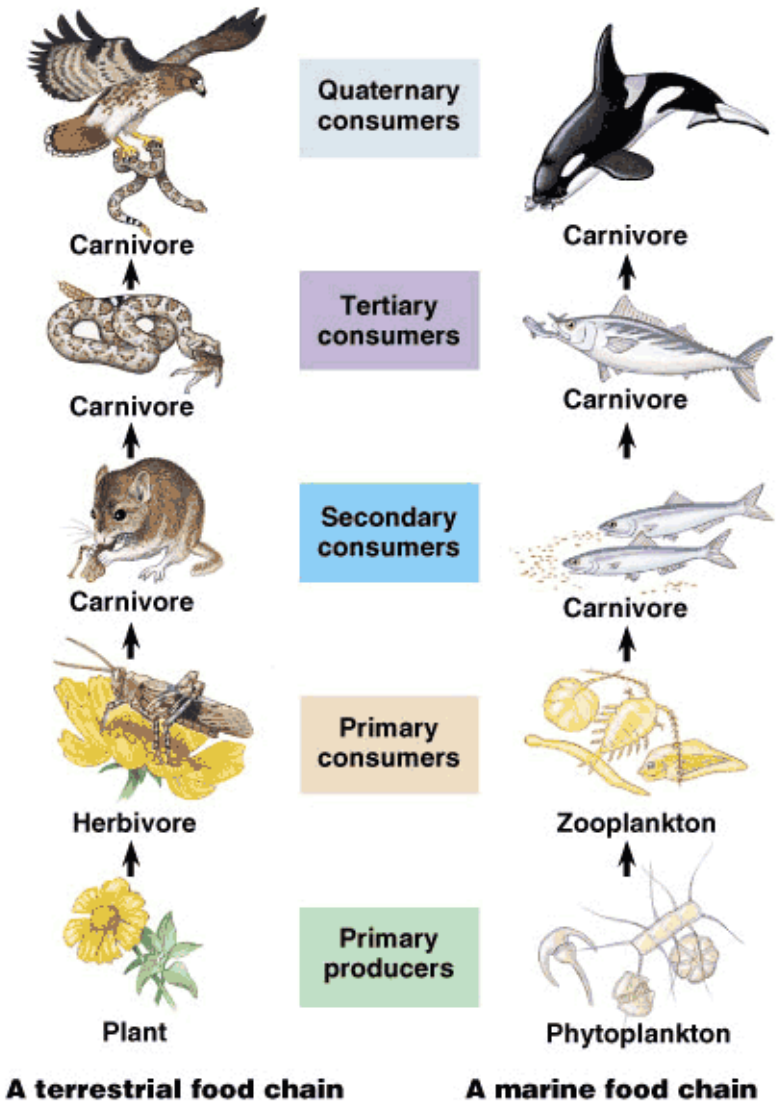

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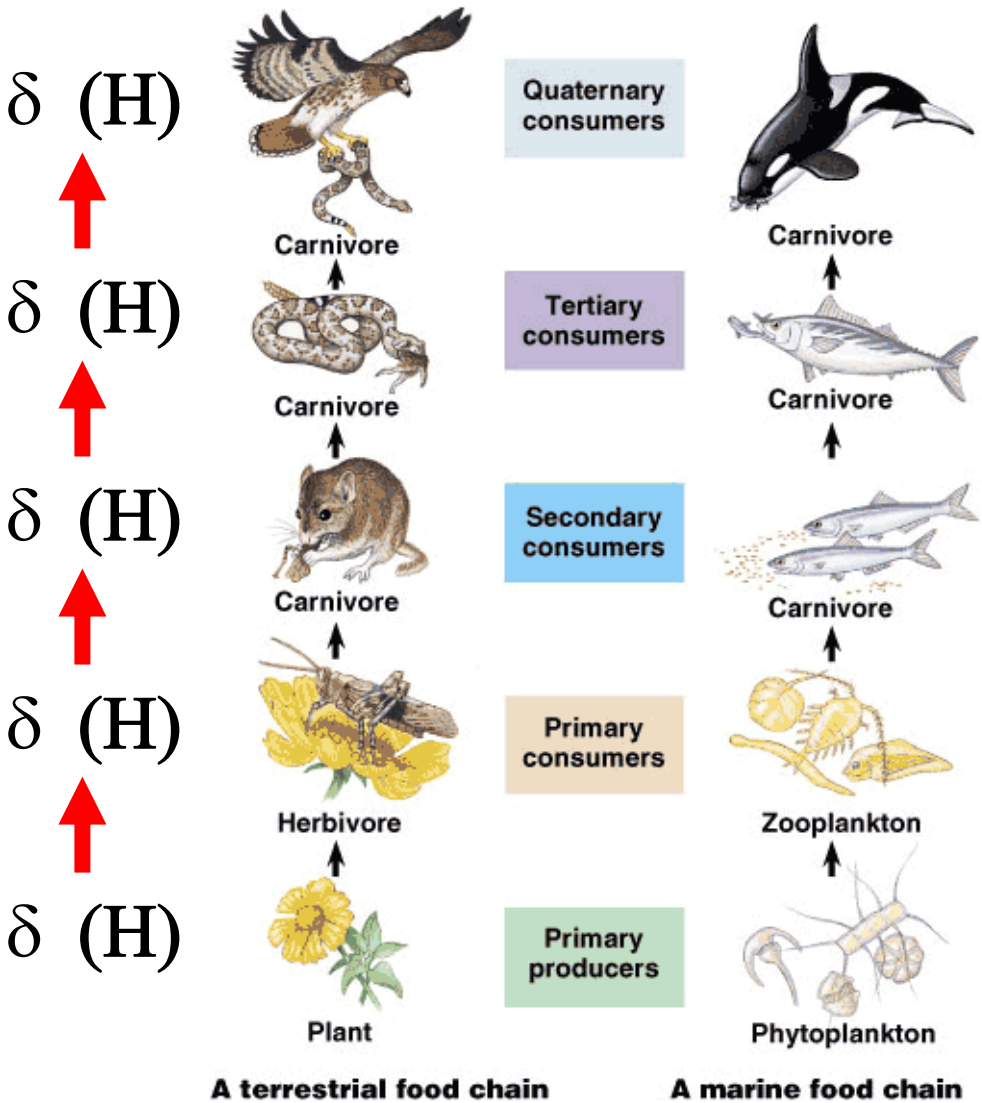
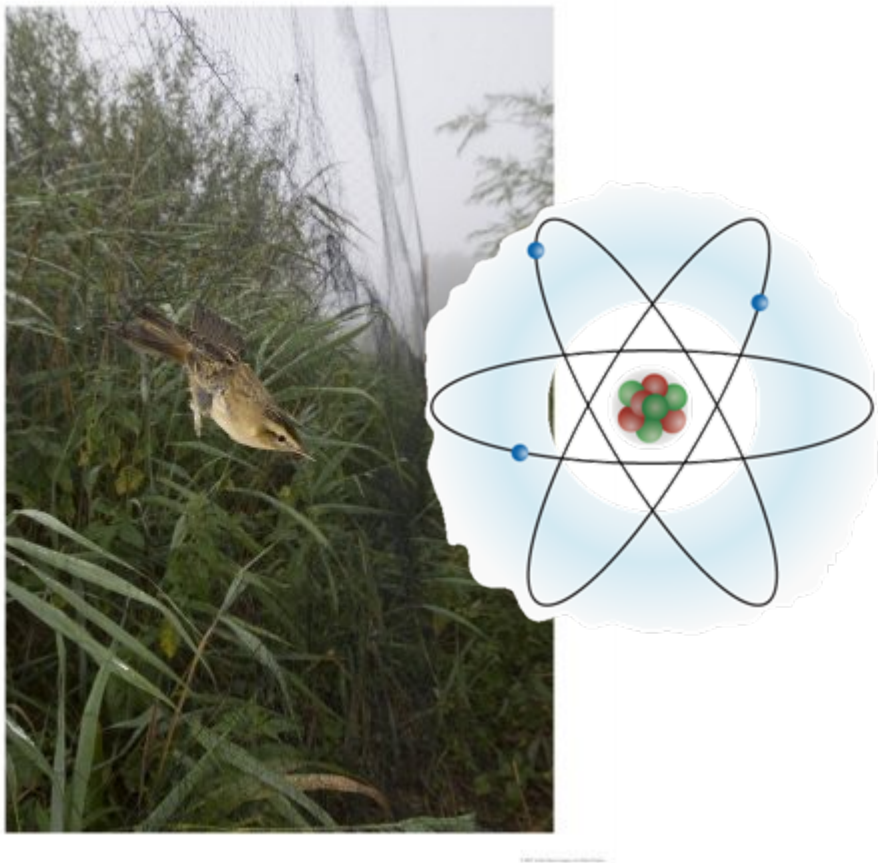


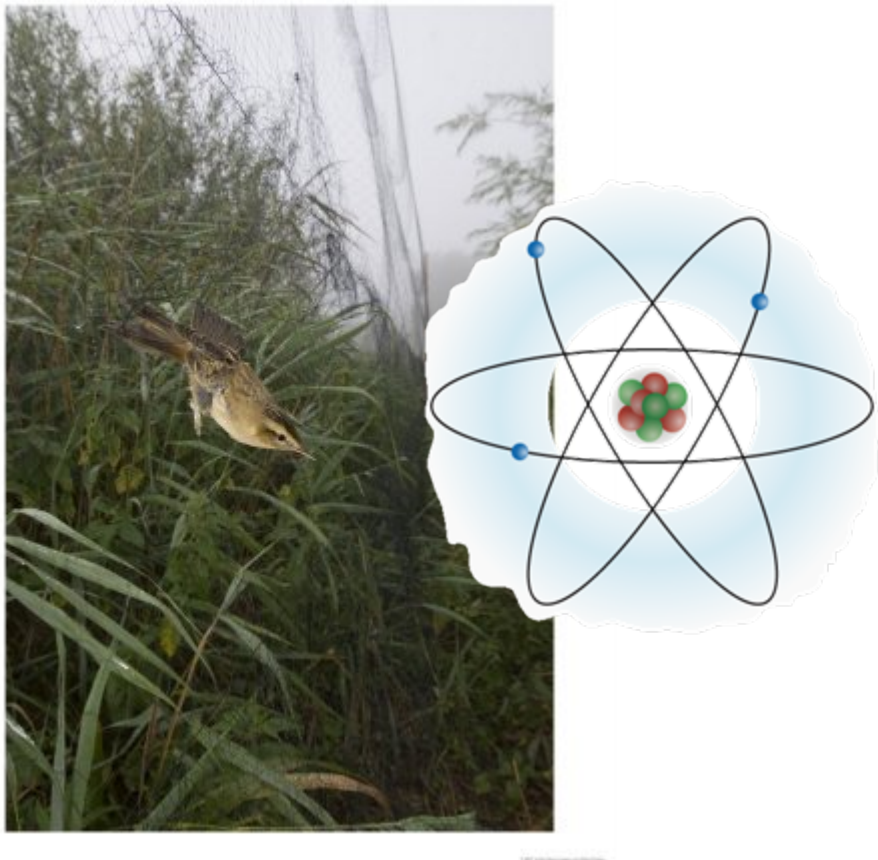
How can we use isotopes to identify migration routes?

- Focus on important migration bottlenecks
- Identify where birds are going and coming from

How?



How?

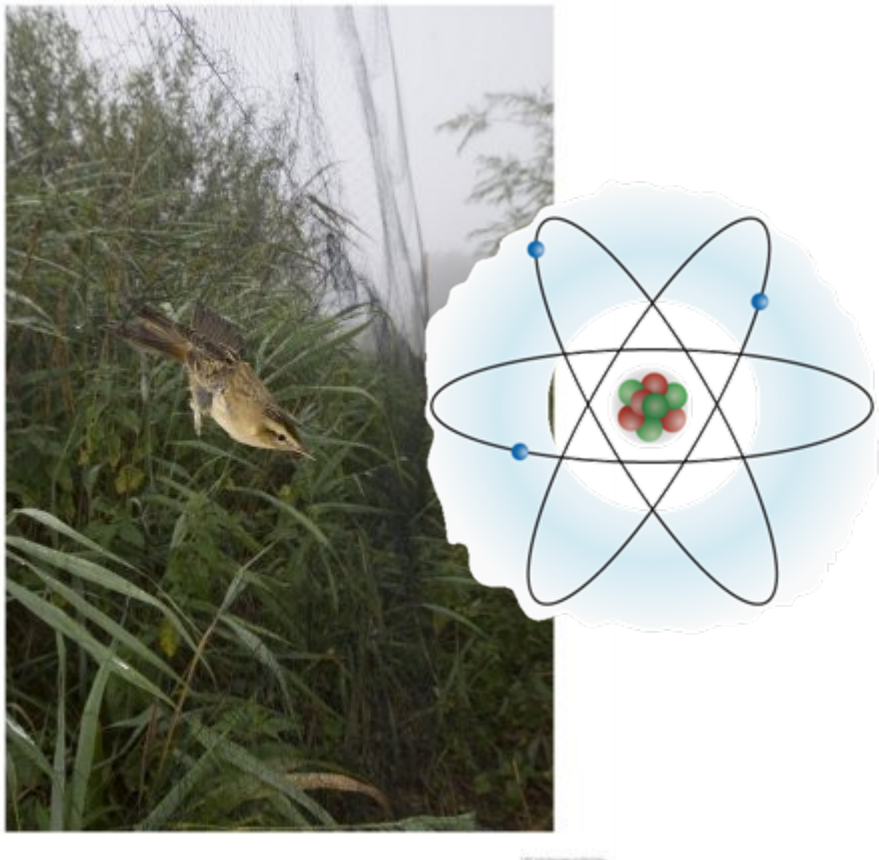


Blood

Feathers

Nails

Different Timelines



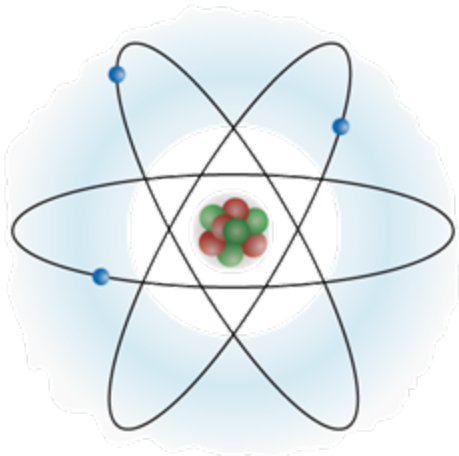
Blood

Feathers

Nails

Timelines

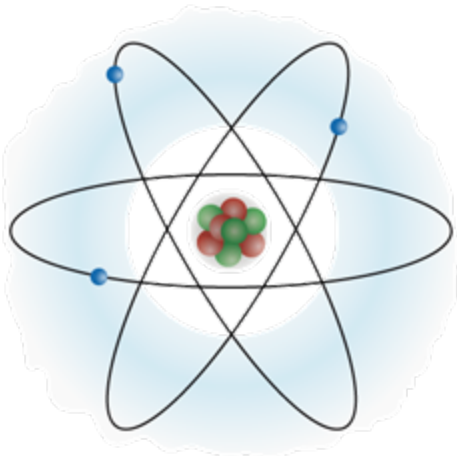
Blood



Timelines

- Blood cells are constantly replaced but can last for more than 3 months

Blood

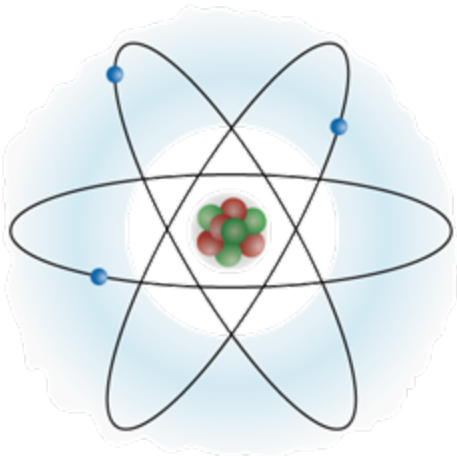


Timelines

- Blood cells are constantly replaced but can last for more than 3 months

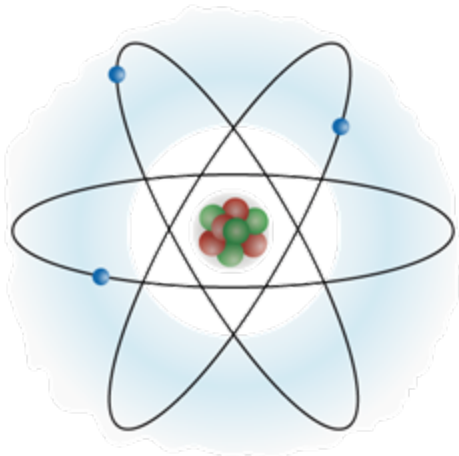
Blood

- A sample can have a highly variable isotope signal



Timelines

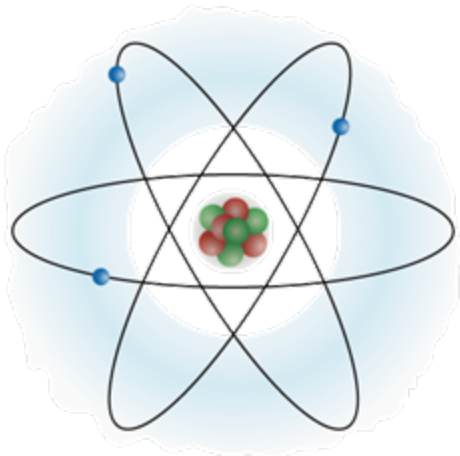
Nails



Timelines

- Also slowly replaced over time . . .

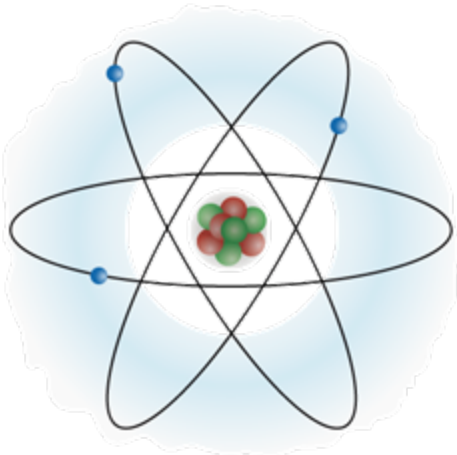
Nails



Timelines

- Also slowly replaced over time . . . but doesn't mix

Nails

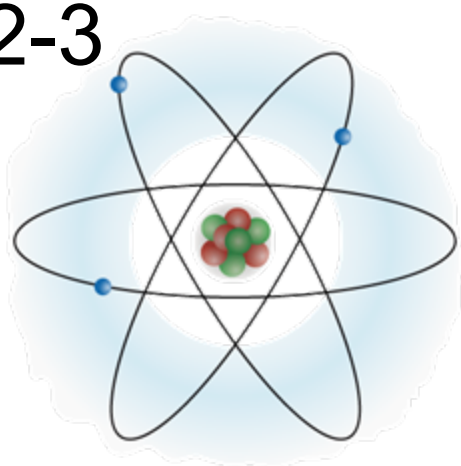


Timelines

- Also slowly replaced over time . . . but doesn't mix

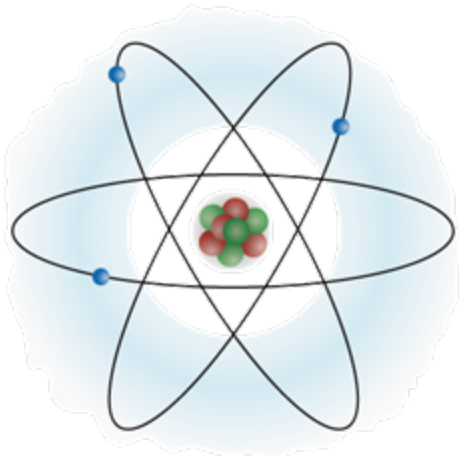
Nails

- A sample will give the isotope signal for where the bird was over the last 2-3 weeks



Timelines

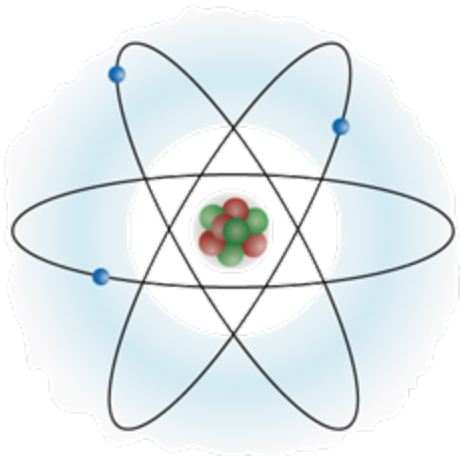
Feathers



Timelines

- Only replaced 1 or 2 times per year

Feathers

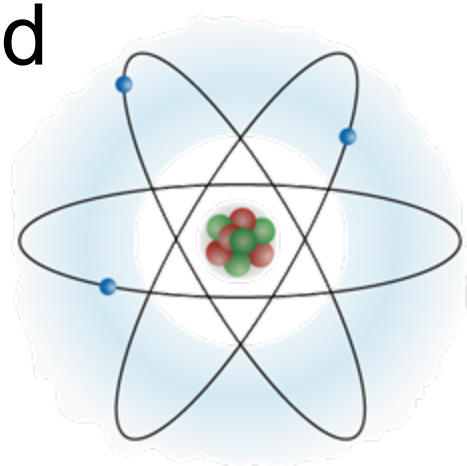


Timelines

- Only replaced 1 or 2 times per year

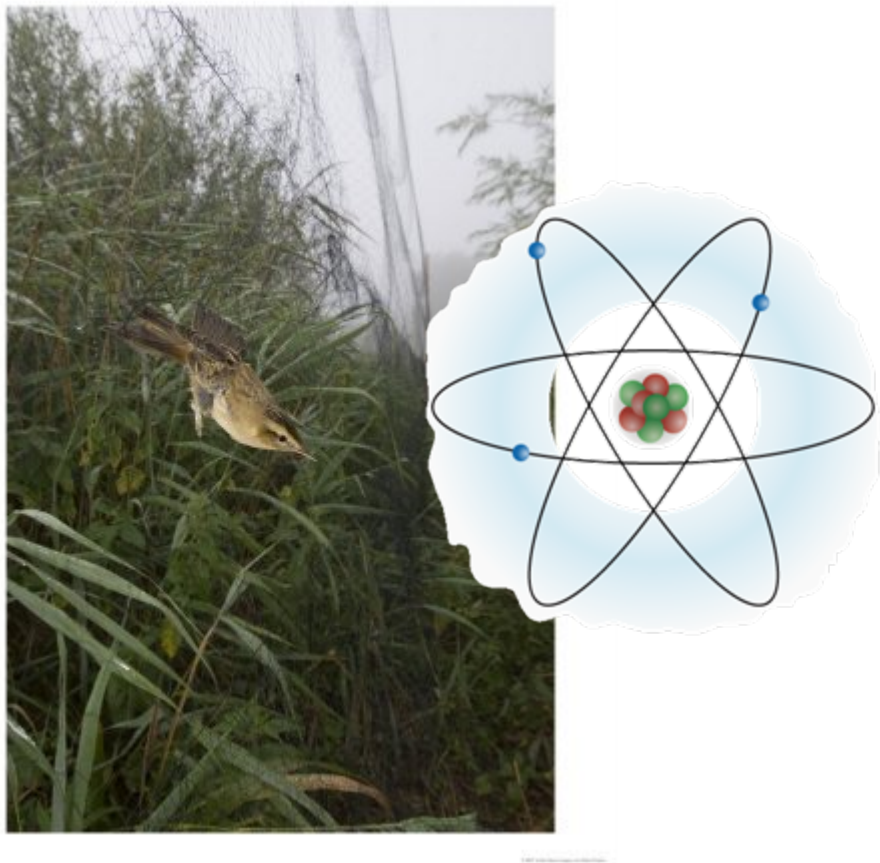
- A sample will give the isotope signal for where the bird was when it molted

Feathers

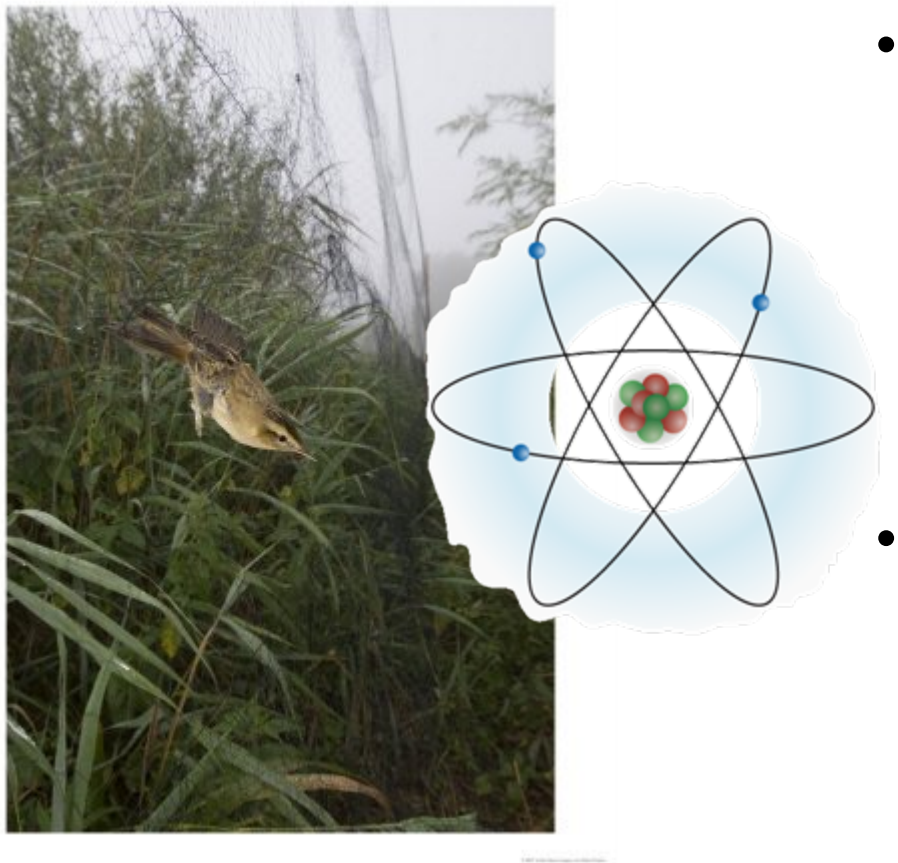


Different species molt at different times and thus at different places

When?

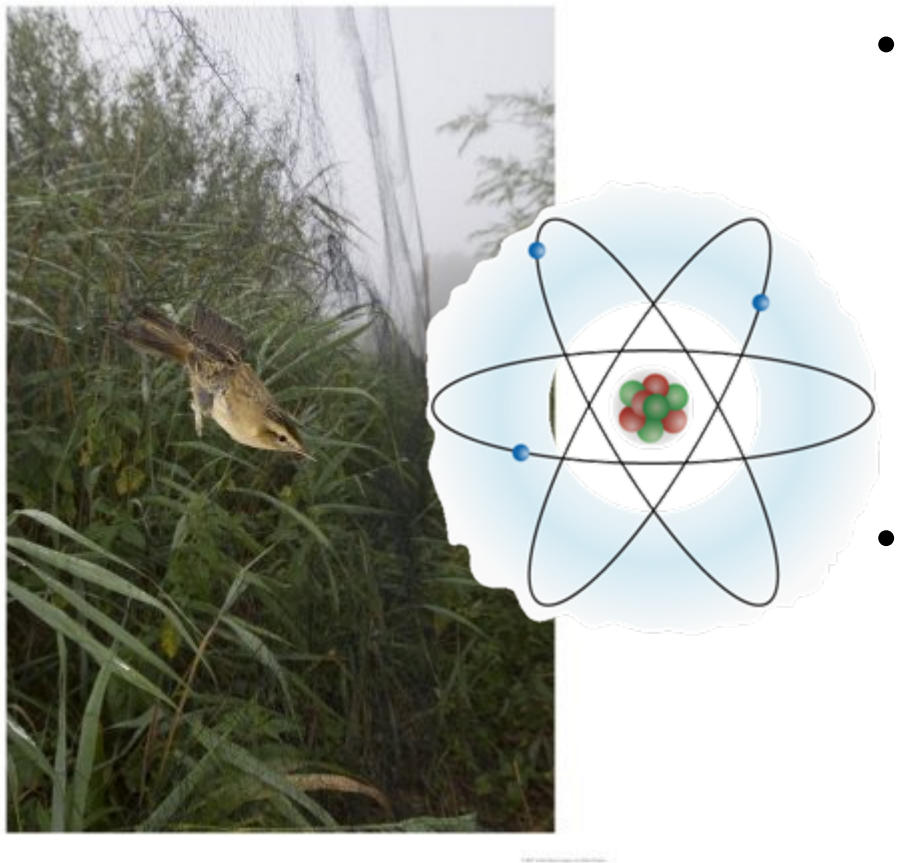


When?



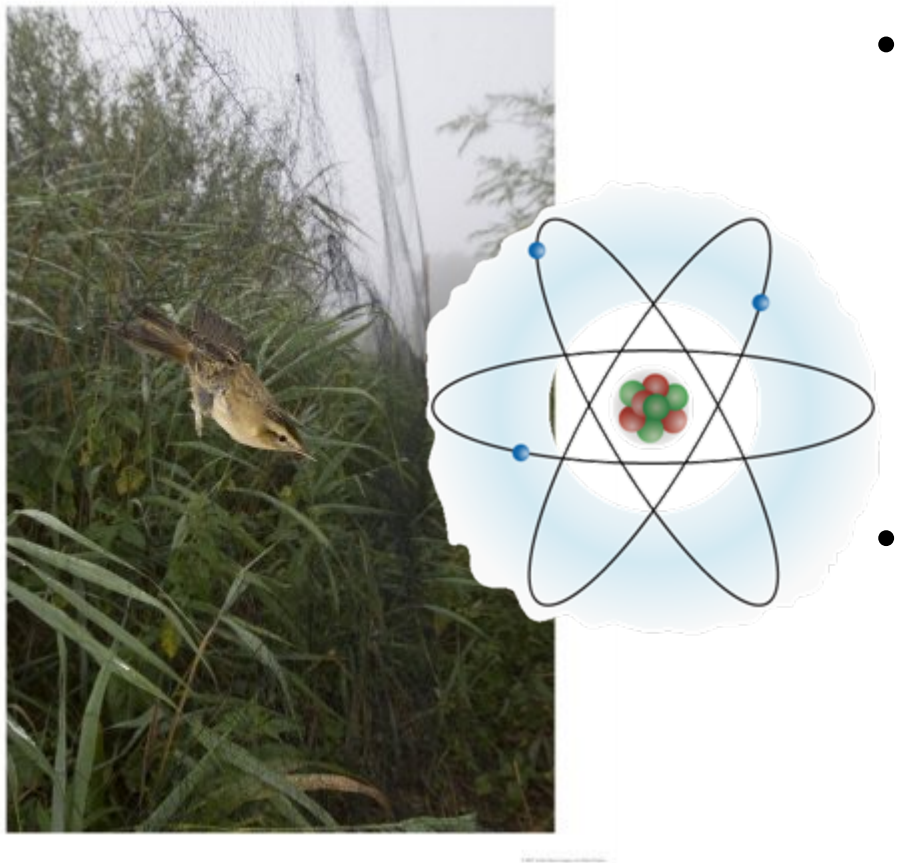
- Spring
- Fall

When?



- Spring
  - Ideal for species that molt in the summer
  - Nails – winter location
  - Feathers – summer location
- Fall

When?

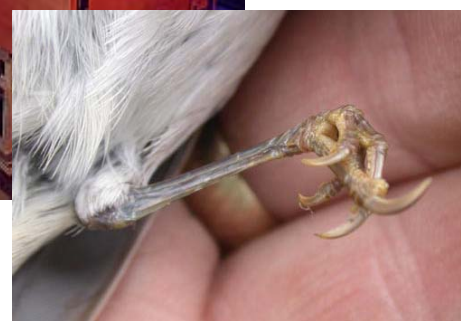


- Spring
  - Ideal for species that molt in the summer
  - Nails – winter location
  - Feathers – summer location
- Fall
  - Ideal for species that molt in the winter
  - Nails – summer location
  - Feathers –winter location

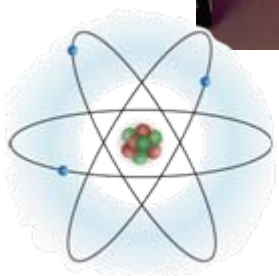
Final Picture

- Collect feather and nail samples
- Information about where birds are going and where they have been

Feathers



Nails



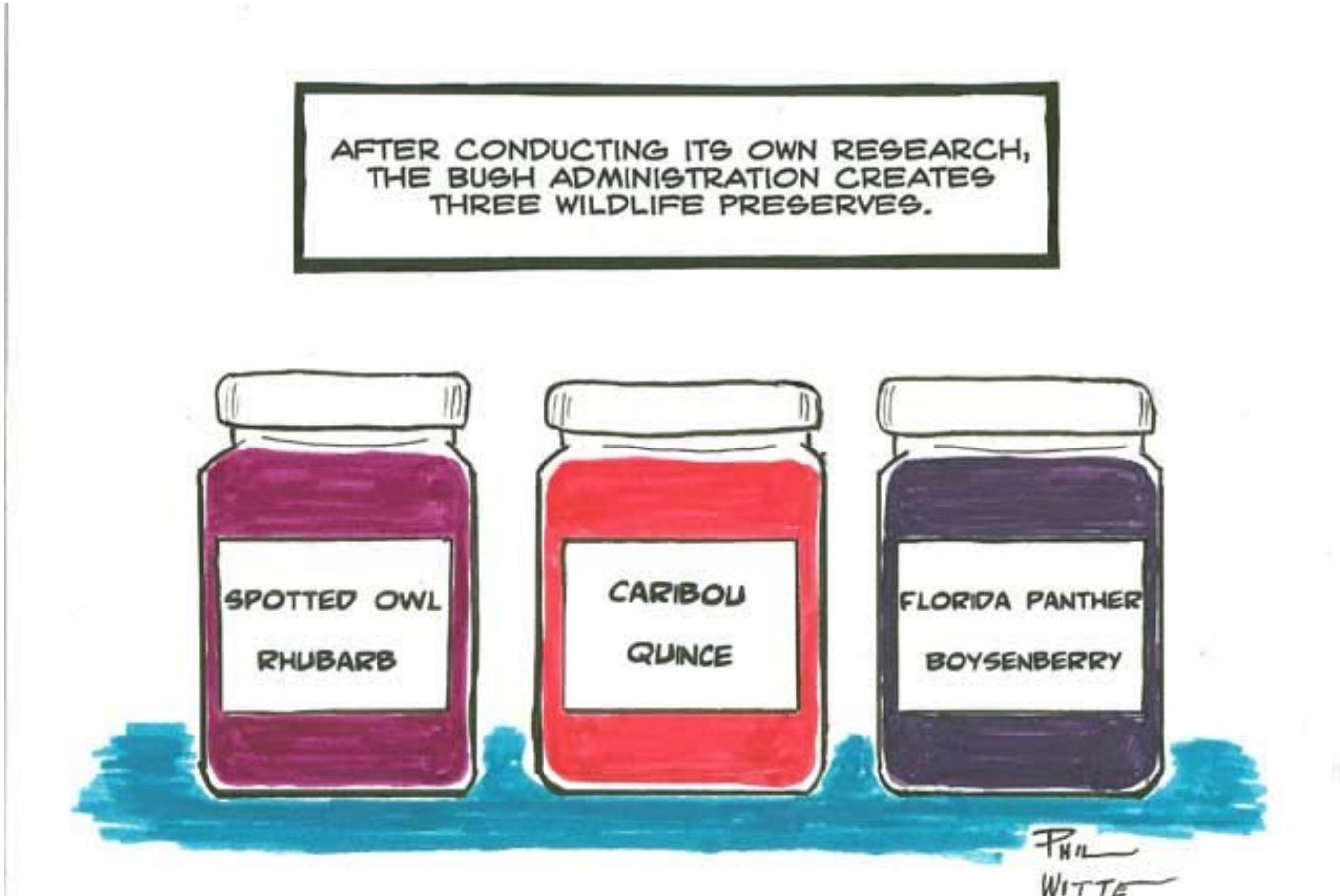
Avian Migration

- What is migration?
- History of avian migration
- Evolution of migration
- Navigation, how do birds migrate
- Measuring migration behaviors
- Energetic demands of migration
- Why do we care about migration?

Conservation of Migrants

Conservation of Migrants

- Populations of most species are declining



Conservation of Migrants

- Populations of most species are declining

- Conservation efforts have typically focused on breeding ecology

Conservation of Migrants

- Populations of most species are declining
- Conservation efforts have typically focused on breeding ecology
- However, birds only spend 2-4 months on breeding grounds

Conservation of Migrants

- Migration can account for > 50% of mortality

- Events during migration can affect reproduction and future survival