MIGRATION

• Unquestionable one of natures most impressive adaptations

• Human records of migration go back as far as recorded time (I Ching)...some of the ideas were BIZARRE
  – Aristotle understood migration of cranes between Asia Minor and the Nile, but thought smaller birds hibernated
  – Because of the seasonal migration of barnacle geese from England the myth was that geese were produced from goose barnacles

MIGRATORY FEATS

• In North American, an estimated 5 billion land birds migrate to and from central and south America annually
  – A blue-winged teal banded on the St. Lawrence River near Quebec was recovered in Guiana 27 days later = 3,300 miles
  – A Lesser Yellowlegs was banded on coast of Massachusetts and shot on Martinique 6 days later = 1,930 miles

Red Knot & Arctic Tern

• The Red Knot migrates from Baffin Island to Tierra Del Fuego w/ Delaware Bay as the primary staging area
• The Arctic Tern migrates between the Arctic and Antarctic for a total distance of 10,000 miles

Golden Plover and Ruddy Turnstone

• The Golden plovers from Alaska migrate 2,500 miles to winter on the Hawaiian Islands
• Ruddy Turnstone flies over 650 miles /day at > 50 mph

The record-holder:
Bar-tailed Godwits fly nonstop from staging groups near breeding area in Alaska to wintering grounds in New Zealand (nearly 7000 miles)

WHAT IS MIGRATION?

• Migration is the predictable, seasonal movement of individuals in response to variation in climate and / or resource availability
  – long distance
  – Round trip (not one way = dispersal)

• Migration differs from NOMADISM by predictability.
  – Nomadism is movement related to unpredictable changes in climate and resources (crossbills)

• Irruptions = irregular movement between consistent or inconsistent locations
  – Invasions of winter finches in response to severe winter
**WHAT IS MIGRATION?**

- Historically, we viewed migration as an escape from hostile climates, limited food, predation, etc.
- More recently, migration is viewed positively as a means to exploit temporarily favorable opportunities.
- This changed our perception to neo-tropical migrants from temperate birds that are trying to escape the winter to tropical birds taking advantage of abundant food and low competition.

**EVOLUTION OF MIGRATION**

- Benefits of migration must be substantial for individuals to take such extreme risks.
- Some hypotheses assert that migrant landbirds evolved from tropical ancestors moving small distances to take advantage of:
  - changing resources
  - reduced competition
  - and less predation.

**COSTS OF MIGRATION**

- Cost of migration is HUGE – more than 50% of the North American migrants do not return the following spring.
  - Of the 100 million waterfowl that migrate south annually, only 40 million return.
- Flight is energetically costly and migration exposes birds to lethal weather events, increased predation risk, and other hazards (buildings, towers).
- There is also a temporal cost associated with the reduced time for reproduction.

**FUEL FOR MIGRATION**

- How do birds cope with physiological cost of migration?
- Many species exhibit periods of hyperphagia before and during migration to build lipid reserves.
- Fat yields 2 times more energy and water per gram than protein.
- 39 Kilojoules / gram for lipid versus 17 / gram for protein.

**FUEL FOR MIGRATION - STOPOVER AREAS**

- Most lipid reserves are stored under the skin, in peritoneal cavity, and in muscle tissue.
- A bird can double its body mass in a few days if food is available.
- Black pole Warblers heading for South America nearly double their body mass from 11 to 20 grams.
- Lipids are Labile = added to body quickly and burned very efficiently.

- Regular refueling is common on both spring and fall migrations.
- Many passerines fly several hundred kilometers and then stop to refuel while others fly until their fat reserves are exhausted.
- Shorebirds in particular have important staging areas like Copper River Delta in Alaska, Bay of Fundy, and Delaware Bay.
Various authors have tried to derive formulas for the "gas mileage" based on the depletion of weight, timing of arrival, and distance between points in migration.

The potential flight range of a migrant is a function of the fat load, tail and head winds, and water loss.

Generally, equations conclude that small migrants can cover about 2500 km in 100 hours if 40% of their weight is in fat. That will get them across any of the world's major geographical barriers to migration.

How do we know birds can navigate?

We displace them and determine if they can find their way back...

White-throated sparrows displaced from wintering areas still find their way back to breeding grounds: illustrates orientation.

How birds find their way across large expanses of unfamiliar terrain has fascinated ornithologists for centuries.

Individual Wood Thrush banded here at the UD woodlot have returned to the exact spot after wintering in South America.

A Manx's Shearwater returned to its nest burrow in Wales 12 days after release from Boston.

What enables birds to accomplish these feats of orienteering?

All birds have some homing abilities enabling them to find nests, feeding grounds, breeding territories, etc.

Homing pigeons can return to lofts after flying 800 kilometers per day over unfamiliar terrain.

Navigation is an extension of homing abilities that allows birds to use cues to not only know where they are, but also, where they need to go.

Navigation is not just for migration:
- feeding sites
- nest sites
- roost sites

Wandering Albatross:
- 15,000 km (9500 mi)
- 30 days
- trip made during the breeding season

Northern Gannet:
- 63% return rate
- displaced ~400 km
- traveled 185 km/day
Adult starlings displaced south during autumn migration compensated and moved northwest (right circle) to normal wintering grounds

Young starlings continued southwest (left circle) and thus ended up south of the wintering grounds

Map and Compass

- To navigate birds must have both a map and a compass
- Before you can use a compass you must determine where you are in relation to where you want to go
- A bird in an unfamiliar setting is able to gain the necessary information to orient itself and navigate back home
- To explain bird navigation we have the “map-and-compass” theory
  - The compass gives the direction and provides the correct orientation
  - The map provides information about your present location
- There are multiple means birds can use to determine compass directions but the map is not clearly understood

Navigation Cues

- Cues birds use to establish location and direction
- Visual
  - Landmarks
- Solar Compass
- Stellar Compass
- Olfactory Cues
- Magnetic Cues
- Learning

Visual Landmarks

- Both diurnal and nocturnal migrants rely on landmarks (mountain ranges, coastlines, rivers, water bodies, major cities) to determine location
- Landmarks often concentrate migrants acting as a funnel where large numbers of individuals occur
  - Can provide learning opportunity for juveniles
  - Examples:
    - Straight of Gibraltar funnels Eurasian migrants around the Mediterranean Sea
    - Cape May New Jersey in North America
- But landmarks cannot explain navigation in novel environments

The Sun Compass

- A famous study with homing pigeons equipped with frosted contact lenses to limit vision but still allow light to pass
- Individuals flew blind 170 kilometers back to their lofts
- First proof that birds were using other cues to migrate besides visual landmarks

The Sun Compass

- Because the position of the sun changes during the day birds must be able to compensate for changes in the angle of the light
- Geoffrey Matthews (1951) released pigeons from unfamiliar sites in a range of weather conditions and times of day
  - Showed that pigeons flew directly home when sky was clear and fared poorly during cloudy weather
  - Also showed that pigeons compensated for time of day
  - The position of the Earth relative to the Sun changes 15 degrees/hr
  - Therefore, sun compass must be time compensated
### THE SUN COMPASS

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Details</th>
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</thead>
<tbody>
<tr>
<td>1. Matthews</td>
<td>Proposed sun-compass hypothesis; others proved it</td>
</tr>
<tr>
<td>2. Kramer</td>
<td>Used bulb to make sun appear to stand still; starlings continued to compensate and made predictable errors in drinking from a cup after being trained to particular cup</td>
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<tr>
<td>3. Emlen and Penney</td>
<td>With penguins – released in interior Antarctica followed sun to return to coast</td>
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<td>4. Hoffman</td>
<td>Clock shifting experiments proved the clock's existence</td>
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*Gustav Kramer showed that starlings could orient in the correct direction as long as they had a view of the sun. When the apparent position of the sun was changed via mirrors, the birds re-oriented. The orientation remained for many hours, the birds were compensating for the movement of the sun via their internal clocks.*

### THE STAR COMPASS

<table>
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<tr>
<th>Experiment</th>
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<tbody>
<tr>
<td>Sauer (1957, 1959)</td>
<td>First demonstrated that birds use a star compass</td>
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<tr>
<td>In a planetarium, caged Garden Warblers would orient north under a &quot;spring&quot; sky and south under a &quot;fall&quot; sky</td>
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<tr>
<td>When the experimenters turned the stars off the warblers became disoriented</td>
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<tr>
<td>When they rotated the north-south axis of the sky 180 degrees the warblers also reversed their headings</td>
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*Experiments in planetariums show that birds can navigate using stars. When "correct" stars are presented birds exhibit Zugunruhe in the correct direction. And in the wrong direction when the position of the key stars were rotated to incorrect positions.*
THE STAR COMPASS EMLEN'S EXPERIMENTS

- Indigo Buntings in a planetarium oriented north when spring sky was presented and south when a winter night was presented
- They became disoriented when the planetarium was turned off and reversed orientation when the axis of the sky was reversed

- Assumed that Indigo Buntings oriented via the North Star because it does not change position
- Not observed...instead they used constellations within 35 degrees of the North Star
- Buntings were familiar with all major constellations in the Northern Hemisphere (Big Dipper, Little Dipper, Deneb, Cepheus, Cassiopeia)
- When one is blocked out, they use another

THE STAR COMPASS EMLEN'S EXPERIMENTS

- Emlen also manipulated the seasonal physiology of two groups of Buntings
  - Group 1 was induced for northward spring migration
  - Group 2 was induced for southward fall migration
- Exposed both groups to the same sky and the Buntings oriented properly dependent on their physiological state
- Showed that migratory orientation is under physiological control

OLFACTION

- Presently, not much research related to olfactory migration cues but some birds can orient via sense of smell...at least locally
- EXAMPLE: Leach's Storm Petrels recognize their nesting burrows based on olfaction
- Experiments on homing pigeons are equivocal
- At best, olfactory cues supplement other navigation systems

GEOMAGNETISM

- The geomagnetic fields of the Earth provide a map of horizontal space
- The intensity (declination) of the magnetic field changes with latitude providing a reliable cue about geographic position
- Ornithologists were slow to accept that birds could detect the Earth magnetic field, but now accepted

GEOMAGNETISM

- Magnetic compass helps explain how birds can maintain direction under total cloud cover or in situations where both celestial and visual cues are obscured
- Radar studies show that flights under these conditions are not as accurate as on clear nights
- But, birds usually maintain direction
GEOMAGNETISM EXPERIMENTS

- In the 1960’s, experiments of the European Robins in steel cages showed that they reversed orientation when the magnetic field was reversed.
- In the 1970’s, experiments with homing pigeons wearing bar magnets found they could not navigate on cloudy days.
- Control individuals wore brass bars navigated correctly.

- Green (1974), fitted homing pigeons with electrical caps that could produce a magnetic field.
- Under overcast conditions, reversing the direction of the magnetic field reverses the course of the pigeons.
- Presently, well accepted that birds can sense and orient using the magnetic field as a navigation clue.
- Sense is extremely sensitive….a 10% change in the magnetic field can disrupt the orientation and it can take up to 3 days for birds to readjust.

- Cochran et al. (2004)
  - Exposed transmittered Gray-checked Thrushes in spring to eastward-turned magnetic fields.
  - Followed them for up to 1100 kilometers.
  - Instead of heading north, experimental birds flew westward.
  - On subsequent nights, when they had access to sunset, the same individuals migrated northward again.
  - Suggests that birds orient with a magnetic compass calibrated daily from celestial cues.

MAPS AND COORDINATES

- If a bird is to reach a destination, it must know where it is relative to that destination.
- It must have a map.
- How birds get their bearings in an unknown location is not yet understood.

NAVIGATION AND LEARNING

- Like many animal behaviors, navigation is part innate and part learned.
- Temporal patterns of migratory activity have some endogenous basis.
  - Migratory preparations as well as the duration and pace of migration are linked to endogenous circannual rhythms.
  - The length of nocturnal behavior in the lab related directly to migratory distance.

- Populations of the Blackcap differ in migration route and magnitude correlated with distance each population normally migrates.
- Blackcaps from migratory populations show intense Zugunruhe while individuals from non-migratory African populations show very little.
- Helbig (1991) provided evidence for genetic basis of migratory direction because hybrids were intermediate in orientation between parent populations.
NAVIGATION AND LEARNING

- Nestling Buntings hand reared without seeing the sky cannot orient when first exposed to the night sky.
- They must see the sky regularly to choose migratory direction while they learn the constellations.
- Axis switching from the north star to Betelgeuse causes a re-orientation in the Buntings.
- Buntings learn the sky compass.

NAVIGATION AND MIGRATION

- Past 25 yrs has provided major discoveries in bird migration and navigation.
- Only recently has magnetic orientation been widely accepted.
- We still can not yet explain in a step-by-step process how a migratory bird returns with incredible precision to specific spots after traveling thousands of miles over unfamiliar terrain.

Migration Research and Conservation

- The first BIRDRAD unit was developed by the Clemson University Radar Ornithology Laboratory 1998.
- The nationwide network of Doppler weather radar is revolutionizing wildlife research and management.
- Linking migration to landscape features.

Bird migration, 5-30-2000.