ANIMAL COGNITION:

1. Knowledge of Where (= Navigation)
2. Knowledge of When, What, Who and How Much

Snake may be the same individual observed 2 years ago in same place.

Home range may be ~3 acres. Can it navigate efficiently within this home range?

NAVIGATION: How do animals get from point A to point B and maybe back to point A?

Navigation
process of determining and maintaining a course or trajectory from one place to another

Types of Navigation
simple  beacon orientation
complex  beacon orientation + estimation of relative position
Simple Navigation

**beacon orientation**
process of orienting towards or away from some beacon which is emitting or absorbing energy

orienting directly to beacons

Mousehole as Beacon

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In homing by digger wasps (see previous lecture), the pine cones became beacons for the mother wasp.

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Simple Navigation cont’d

**using beacons as compasses**

Moths use a lunar compass

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Why moths fly into a light

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**using beacons as compasses** (cont’d)

Birds migrate long distances.

In the lab, they enter a state called 'zugenuhe' = state of restlessness.

Indigo Bunting

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Using an arena with an ink-pad in the center, surrounded by paper, you can map the direction of their restless behavior!
Indigo buntings in autumn are heading southeast. Part of the migration occurs at night! HOW to maintain direction at night?

Before GPS systems, ships navigated at night, using the stars. In other words, they used a stellar compass.

The stellar compass hypothesis tested by putting birds into a planetarium.

Position of stars in planetarium was shifted for a European bird species:

"Autumn sky": Birds should be moving south.

"Spring sky": Birds should be moving north.
Position of stars in planetarium was shifted:

- "Spring sky": warblers moved north
- "Autumn sky": warblers moved south

What features of the night sky are used? Do birds know innately how to use these features? Or do they learn them?

Clues from human behavior: The north star has been used in marine navigation. Why?

- a. It's the brightest star in the sky.
- b. It's a different color than the rest.
- c. It lies directly over the north pole.
- d. Its position doesn't change through the night like other stars.

Star trail map over Hawaii, showing that the north star is the only star that does not move through the night. Somehow, humans learned this and used it.
Using the Stars to Navigate

Steve Emlen set up three groups of indigo bunting chicks in the planetarium:
1. chicks reared in a room with a diffuse light at night
2. chicks reared with a normal star map that rotates around the North Star.
3. chicks reared with an abnormal star map that rotates around Betelgeuse (a star in the South).

Conclusions

1. Indigo buntings are using the stable point in sky as a reference when migrating.
2. Buntings appear to learn this point as young birds.
How do monarch butterflies navigate to these sites and back?

**Hypothesis:** They use a sun compass.

If so, the sun compass must be time-compensated. Here's why:

As sun moves across sky, angle maintained relative to sun would have to be changed appropriately.

To test for use of a time-compensated sun compass,

Investigators engaged in clock-shifting.

Raised a late-shifted group which 'thinks' it's 6am when it's really noon.

Raised a control group which 'thinks' it's noon and it is!

Release both groups at noon, real time

At noon in northern latitudes, sun is in the southern part of the sky.

Hence, at noon, a butterfly attempting to fly south should fly in direction of the sun.

Late-shifted butterfly 'thinks' it is 6 am when it is actually noon.

At 6am, sun is in *east*. So butterfly should fly 90 degrees away from sun.

BUT... it is actually noon and sun is really to the south.

So... the butterfly ends up flying *WEST*.

Control butterflies headed towards sun, as expected.
Sea turtles migrate too, out to the ocean as hatchlings and then back to their natal beach as adults.

Hatchlings maintain a highly directional outward-bound course. HOW?

Moving Towards the Water

1. Dunes and associated vegetation form a dark silhouette.
2. Beach slopes down in the direction of the water.
3. Ambient light is reflected from the ocean, making that region brighter.

Moving Off the Beach to the Open Ocean

Type of apparatus in which cues were manipulated.

Using this setup, hatching loggerhead sea turtles use both slope and brightness to move to the water.

Since waves run parallel to the beach, swimming into the waves moves them towards the open ocean.

Continuing Out into the Open Ocean

Remarkably, hatchlings maintain an outward bound heading even after the waves disappear. HOW?

Perhaps hatchlings are using a magnetic compass.

Testing the Magnetic Compass Hypothesis

Hatchlings tethered and allowed to swim towards light in the east. Light was then turned off. Hatchlings maintained an easterly orientation, even in total darkness.

Next, hatchlings were again allowed to swim towards a dim light in the east.

However, this time when the light was extinguished, magnetic field within a coil was reversed. Hatchlings swam westward!!
Further experiments suggest that the magnetic compass is acquired as hatchlings swim into the waves.

The blind mole rat (*Spalax ehrenbergi*) lives underground and uses a magnetic compass to navigate throughout its extensive burrows.

**Complex Navigation**

Involves both beacon orientation (often compass) AND estimation of relative position.

**Relative position**

Where you are now relative to where you were earlier.

**Complex navigation in the desert ant, *Cataglyphis fortis***

- Found in Saharan desert
- A thermophiliac that hunts for heat-stressed prey
- Individuals live together but forage alone (no trail pheromone)

*Cataglyphis* is impressive, unerringly crossing hundreds of meters over barren landscapes devoid of landmarks, and returning home.

The desert ant wanders alone until it finds a prey and then makes a direct line home...

... even though there are no useful landmarks along the way.
A critical displacement experiment gives us insight into how the ant finds its way home.

Nest

NO!

F

Transport in light-proof flask for ca. 1 km and release.

Where does the ant go?

N*

NO!

YES!

This result suggests that the desert ant using dead reckoning to estimate relative position.

Dead Reckoning
Estimation of relative position is accomplished by keeping track of turns and distance walked between turns

Also called path integration, the term was originally 'deduced reckoning' and then abbreviated 'ded. reckoning'.

So that's the 'map sense'. What about the 'compass sense'?

What compass is used to navigate home?

Ants use sun as compass, but if sun is not available, they use the pattern of polarized light in sky.

Homing in Pigeons

Pigeons have been known to engage in homing behavior for a long time, flying home from as much as >1000 miles away.

Pigeons have been used to send messages over long distances.

Pigeons were used in both world wars to send messages when military could not.

Is pigeon navigation different from desert ant navigation?
When the displacement experiment is performed on pigeons, a different result...

Transport 100's of miles and release. Where does the pigeon go?

This result suggests that the homing pigeon is using piloting to estimate relative position.

**Piloting**
Estimation of relative position by using local features in relation to a map

Piloting can allow an animal to steer around unobserved obstacles and towards unobserved goals.

*What is the nature of the pigeon's map?*

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**The Olfactory Map Hypothesis**

The home loft gets olfactory input from various directions, from which pigeons build a map.

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**Evidence that pigeons need olfaction to home properly**

Normal olfaction

Olfaction blocked

*But is this the map sense or compass sense?*

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**But... Problems!**

1. Attempts to replicate these findings at other lofts produced widely differing effects.
2. Odors of the required characteristics and distribution do not seem to exist.
3. Some effects of 'olfactory' manipulations do not seem to depend on the availability of odors.

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**PIGEON HOMING: OBSERVATIONS, EXPERIMENTS AND CONFUSIONS**

CHARLES WALCOTT

“There is some evidence that pigeons may use several cues and that pigeons raised in different lofts under different environmental conditions may prefer to use one cue over another. I believe that it is this flexible use of multiple cues that has led to so much confusion in experiments on pigeon homing.”
Complex Navigation involves both a map sense and a compass sense.

What about the pigeon’s compass sense?

Pigeons are thought to use:
- sun compass
- magnetic compass
- local landmarks when near the loft

Reverse magnetic field and birds fly in opposite directions, but only on overcast days.

SO… sun compass is dominant, magnetic compass is a backup.

Pigeon wearing Helmholtz coil plus battery