# Course introduction

# Outline

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# Expectations of professor

- Start and end on time
- Focus on conceptual understanding
- Make clear what terminology and facts must be learned
- Open to questions – both in class (within reason) and at office hours
- Available by email and on discussion forums

# Expectations of students

- Start and end on time
- Prepare the distributed handouts so you're ready to take notes
  - Paper will work best for a lot of people
  - Electronic notes can work well if you work out a system
- Don't multi-task
- Try to participate

# Structure of presentation

- Required material will be clearly outlined in the notes
  - * This is an answer: it was omitted from the notes for discussion purposes, you should probably write it in
  - *This is a comment: I omitted from the notes because I thought it wasn't necessary for you to study*
- Required terminology will be presented in **bold**
- General ideas and approaches presented in class may also be required; you should take notes on these in your own words

# Why come to class?

- It's required
- Listening and thinking and talking will help you understand concepts, instead of just memorizing
  - Classroom discussion makes the course more interesting and memorable
- Details and terminology should be covered in sufficient detail in the notes; concepts may not be
- *You can't get your money back, so you may as well enjoy the show*

# Why read the book?

- It's interesting
- The book will explain some things in a better way for you personally than I do
- Familiarity improves understanding

# Taking notes

- You will need to develop your own style of taking notes
  - Many people benefit from writing things down, or using their own words
- If a new concept is making sense to you right now, write something that will help you remember
- If there's something I think you all need to write down, I will write it for you (or mark it as an answer)

# Evaluation

- You are not responsible for details unless they are in the notes
  - and not responsible for terminology unless it's in **bold**
- You *are* responsible for relevant ideas and concepts from lectures and readings
- Conceptual questions, logical inference questions and application questions are fair game
  - Practice questions will be available
- Dushoff is responsible only for your midterm/exam evaluation (and only for half of that)

# *Structure of presentation (repeat)*

- Required material will be clearly outlined in the notes
  - * This is an answer: it was omitted from the notes for discussion purposes, you should probably write it in
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# Outline

# Deductive thinking

- Science proceeds by advancing hypotheses and comparing them to facts
- Facts can be observed from nature, or we can construct experiments to test specific hypotheses
- Basic, logical thinking is very *simple,* but it is often not *easy* for humans to think clearly about abstract concepts
  - *Which is more complicated: algebra or hockey?*

## *Algebra (present)*

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

# Hockey (present)

# Outline

# Cards (present)

## *Deductive thinking (preview)*

- You go to a job interview, and are shown some playing cards.
- Some cards are face up, and you can see that they are aces or kings.
- Some cards are face down, and you can see whether they have bicycles or airplanes on the back
- The interviewer asks you to test the hypothesis that all of the aces have airplanes on the back
- Which of the four groups of cards do you need to turn over?
  - *

# Drinks (present)

# Deductive thinking

- You are the manager of a restaurant
- You can see some people's drinks clearly, and tell whether the drinks are alcoholic or not (but not the people's ages)
- You can see other people's faces clearly, and tell whether they are underage or legal-age (but not what they are drinking)
- You want to test the hypothesis that everything is OK:
  - everybody who is drinking alcohol is of legal age
- Which of the four groups of people do you need to check out?
  - * The alcohol drinkers, and the underage people

# Deductive thinking

- You go to a job interview, and are shown some playing cards.
- Some cards are face up, and you can see that they are aces or kings.
- Some cards are face down, and you can see whether they have bicycles or airplanes on the back
- The interviewer asks you to test the hypothesis that all of the aces have airplanes on the back
- Which of the four groups of cards do you need to turn over?
    - * The aces and the cards with bicycles on the back

# Thinking conceptually

- Logical interpretation and inference is simple, but not always easy
  - This is true for everyone
- Being on familiar ground helps us think clearly
  - This will work for different people in different ways: learning facts, stories, mechanisms, etc.
- Practice clear thinking about simple questions

# Outline

# Inference

- Does the last statement *follow* from the first two?
- Cats have four legs. Mammals have four legs. *Therefore*, cats are mammals
  - * Not a valid conclusion
- Cows can fly. Dushoff is a cow. *Therefore*, Dushoff can fly.
  - * Valid conclusion
  - * Based on the assumptions

**Remark: Elm Farm Ollie, the first flying cow**

# Valid conclusion (present)

# Why are simple things difficult?

- Probably because we've evolved to be good at certain kinds of thinking
- Example: training pigeons
  - Pigeons can be trained to do remarkably complicated things with their bills to get food
  - and with their feet to avoid electric shocks
  - but not the other way around!
- Why does this make sense?

# Assignment: Logical equivalence

- Are these two statements logically equivalent?
  - Tall people are mean
  - Mean people are tall
- Are these two statements logically equivalent?
  - Good food is not cheap
  - Cheap food is not good
- Consider this an assignment

**Remark: Assignment. They should satisfy themselves that they understand**

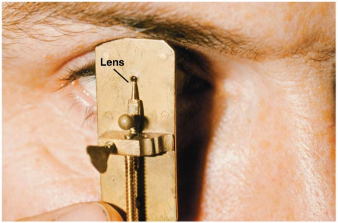
# Logical equivalence

- Statements are **logically equivalent** if they express the same fact in different words. In other words, if either one is true, the other one must be true.
  - And vice versa
- Different people find it useful to think about logical equivalence in different ways
  - Can you construct an example where one is true and the other is false?
  - What would it take for each statement to be true?
  - What would it take to falsify each statement?

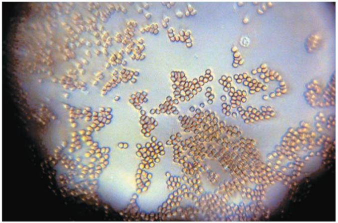
# Outline

# All living organisms are composed of cells

**(a)** van Leeuwenhoek built his own microscopes—which, while small, were powerful. They allowed him to see, for example ...




**(b)** ... human blood cells (this modern photo was shot through one of van Leeuwenhoek's original microscopes).



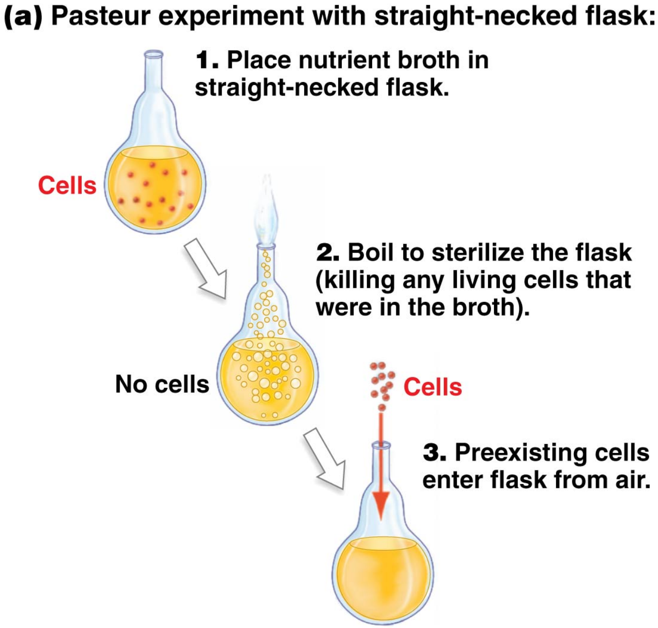


- A **cell** is a highly organized compartment bounded by a membrane
- **Genes** made of **DNA**
- **Proteins** made of **amino acids**
- What about viruses?

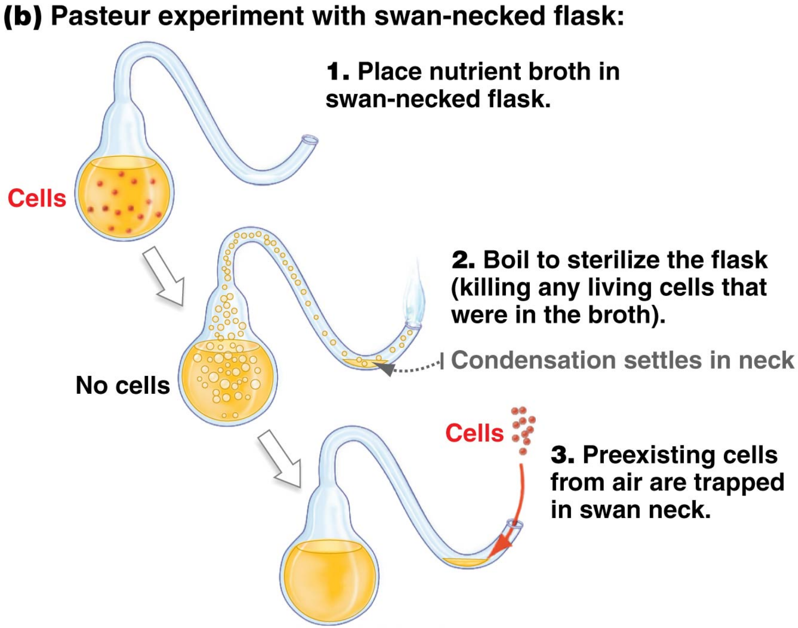
# Where do cells come from?

- Are they generated spontaneously?
  - If we leave damp bread out, molds just appear
- Do they come only from other cells?
  - * Then where did the first cells come from?

# The Pasteur experiment (present)



# The Pasteur experiment (present)



# The Pasteur experiment

- Why was it necessary to have two flasks?
- What if the first flask had also failed to grow cells?
  - * Maybe the broth wasn't the right kind to support growth of cells
  - * Maybe the flask was somehow poisonous or discouraging
- Does this prove all cells come from cells?
  - * Maybe cells can generate spontaneously under other conditions
  - * . . . , but that's not what's happening here

# Outline

# Hypotheses

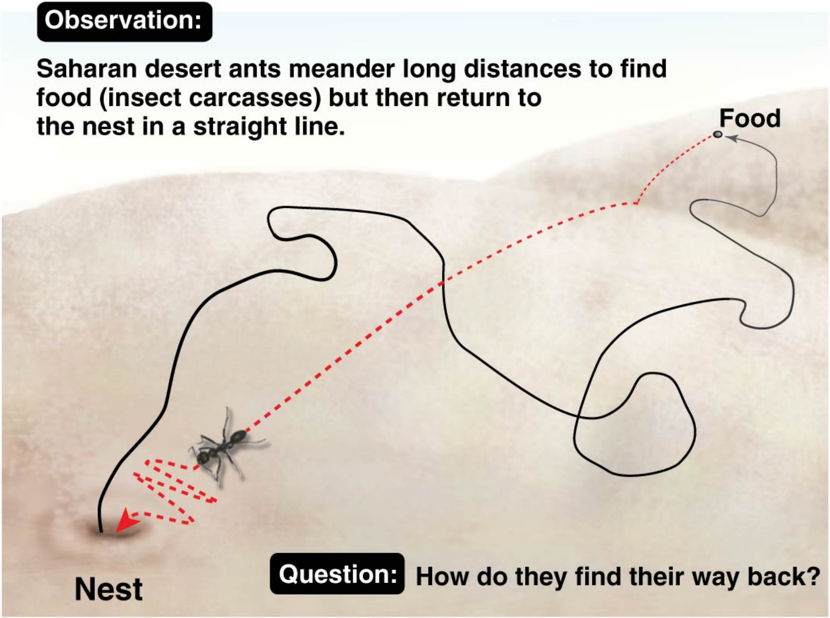
- We pursue science by evaluating **hypotheses** (sing., hypothesis). These are proposed explanations of facts.
- We use hypotheses to make predictions, and use experiments and observations to attempt to **falsify** hypotheses – to prove they are false.
  - Most hypotheses cannot be *proved* to be true, instead, if we fail to falsify them, we say that they are supported
  - If a hypothesis explains many facts, and survives attempts at falsification, we tend to believe it

# Outline

# Example: How do ants navigate through landscapes?

- Many species of ants move efficiently through landscapes while finding food and returning to their nests
- How do ants navigate through landscapes?

# Ant navigation (present)



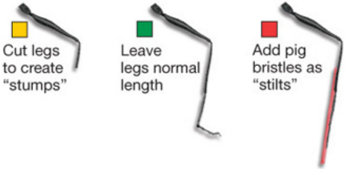
# Ant navigation (present)

**EXPERIMENT**

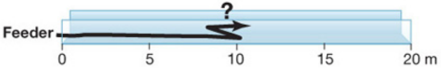
**EXPERIMENTAL SETUP (TEST 1):**

**1.** Ants walk from nest to feeder. Seventy-five ants are collected.


**2.** Manipulation of legs. Three treatments, 25 ants each.



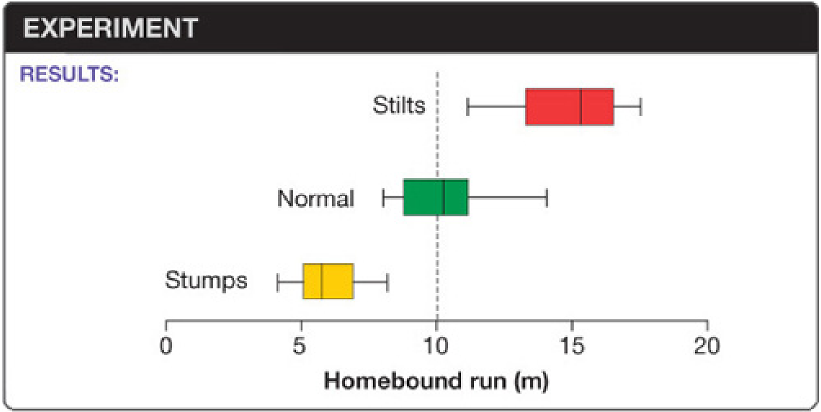

**3.** Ants return "home" from feeder and look for nest hole.




**PREDICTION:**
Ants with stilts will go too far; ants with stumps will stop short.

**PREDICTION OF NULL HYPOTHESIS:**
No differences among the 3 groups.

# *Ant navigation (present)*



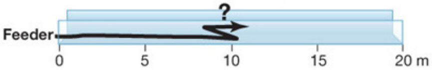
# Ant navigation (present)

## EXPERIMENT

**EXPERIMENTAL SETUP (TEST 2):**

**4.** The three treatments of ants walk from nest to feeder again.


**5.** Ants walk back "home" from feeder again.



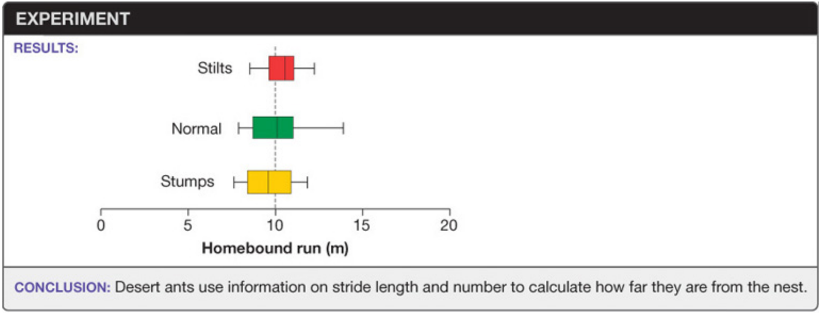


Stilts make leg length and stride length longer

**PREDICTION:**
All three groups will start looking for nest after walking 10 m.

**PREDICTION OF NULL HYPOTHESIS:**
No difference from the result in Test 1.

# *Ant navigation (present)*



# Interpretation

- What would you think if the modified ants didn't navigate normally this time?
  - * That the manipulation messed them up in some way we didn't think of
- Why do we test the normal ants *again*?
  - * As a check on our experimental setup
  - * Replication principle: shouldn't compare modified ants this time to normal ants from last time; many things may have changed
- What should we conclude?
  - * Ants use information about number of steps
  - * Do we think that ants are counting the way that we do?

# Example: Vitamin C

- I want to find out whether Vitamin C is good for mice, so I raise a mouse on a standard diet, with Vitamin C supplement, to see whether it has a long, happy, healthy life.
- What is wrong with this experiment?
  - * No comparison. I don't know how the mouse would have done in the absence of the supplement
  - * I only used one mouse. I don't know if there was something unusual about it.
- * What if I compare two mice?
  - * one will always do better than the other!

# Control

- Good experiments are **controlled**: we have two or more groups that differ only in some factor we want to study
  - flask neck, vitamin C
- Groups should be as similar as possible, except for the factor that we wish to study

# Replication

- Good experiments are **replicated**: each group has more than one **replicate**
  - A replicate is a unit which is subjected to a chosen treatment
    - e.g., a mouse, a troop of baboons, a flask

- Replicates should be **independent**. Replicates in the same group should not have *anything* in common that they don't share with other groups (except for the factor we are studying).
  - What if we put all the mice that get vitamin supplements in one cage, and the others in another cage?
    - * We then have to worry about all possible differences between the two *cages*

- Example: I want to see how injecting a particular vaccine affects mouse behaviour
  - * Treatment mice all get caught and stuck with needles
  - * Give the control mice injections with no vaccine

# Randomization

- Good experiments are **randomized**: units are assigned to treatments randomly
  - First, arrange the experiment
  - e.g., first pick which mice to put into which cages, *then* decide at random which cages get supplements

# Outline

# Observational studies

- Look for ways to collect data that will support or challenge hypotheses
- Scientists are cautious about making conclusions from observational studies
  - * It's hard to know if you've taken everything into account
  - * Experiments are more reliable . . .
- So why do we do them?
  - * You can't always do experiments
  - * Time, practicality, ethics

Bill Lea/Dembinsky Photo Associates/Alamy Stock Photo

# Example: Bighorn sheep

- Why is it hard to experiment?
  - * Sheep live for a long time, and evolution is slow
  - * Hard to replicate conditions, would need a lot of independent populations
  - * Ethical issues
- Without experiments, it's much harder to confirm what's going on

# Assignment: Car Trouble

- A brother calls his sister because something is wrong with his car
- She arrives, and they have this conversation:
  - Sister: I have a tow hitch, and a tow rope, but I obviously can't tow you.
  - Brother: That's OK, I can tow *you*!
  - Sister: I guess so. If we're careful.
- Each person drives their own car. Nothing is wrong with the sister's car. What is wrong with the brother's car?

# More logic

- Whatever doesn't kill you makes you stronger
- If we take this literally, then: Whatever doesn't make you stronger . . .
  - * kills you