



# Optimality, and adaptive feeding





# Animal behavior



- Very active research area, particularly in evolutionary context
- Behavior integrates many aspects of Biology
  - Physiology (e.g., hormones, neurobiology)
  - Genetics
  - Ecology
  - Evolution

# Some areas where evolutionary thinking is applied

- Survival/ avoiding predation
- Feeding/ foraging behavior
- Choosing where to live
- Communication
- Reproductive behavior (sexual selection)
- Parental care
- Social behavior





# Concepts to address today



- Optimality theory – achieving maximal effect for minimal cost
- Application to studying adaptive feeding behavior

# Evidence for natural selection abounds!

- Eurasian oystercatcher feeds on mussels
- Choose “optimal” mussel in feeding:
  - If too small, not enough nourishment
  - If too large, too hard to open
  - Should pick intermediate size
    - Initial models said should pick 50 mm
    - Refined model predicted 30-45 mm because larger ones are covered with barnacles and hard to open



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  - They prefer 30-45mm mussels- model fits data!







# Selection is everywhere!



- Structures & behaviors appear optimally designed by natural selection for functions
  - Cases where non-optimal, infer “trade-offs” - compromises among competing demands



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- Structures & behaviors appear optimally designed by natural selection for functions
  - Cases where non-optimal, infer “trade-offs” - compromises among competing demands
- **The Adaptationist Program**- interpreting data by assuming “the near omnipotence of natural selection in forging organic design and fashioning the best among possible worlds.”  
(Gould & Lewontin 1978)





# Overinterpretation has happened for a long time...



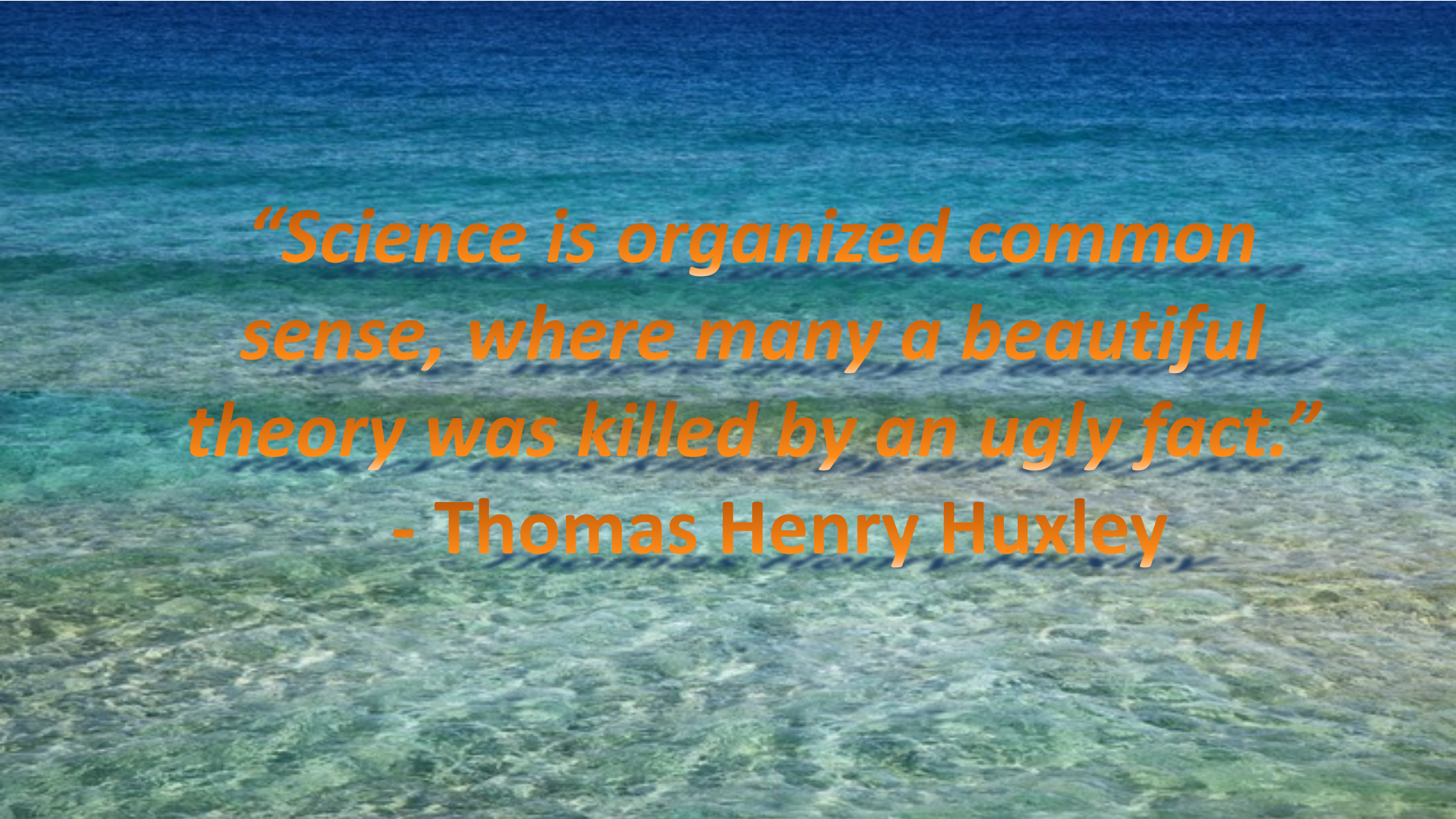
- Spencer asked Galton (pre-1909) to look at his fingerprints
- Galton said he didn't know the function of the patterns, despite people dissecting fingers of unborn children & studying their prints
- Spencer said ridges “obviously” functioned to protect the sweat glands in the valleys



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- Galton said he didn't know the function of the patterns, despite people dissecting fingers of unborn children & studying their prints
- Spencer said ridges “obviously” functioned to protect the sweat glands in the valleys
  - Problem: the glands are actually *in the ridges*.



*“Science is organized common sense, where many a beautiful theory was killed by an ugly fact.”*  
- Thomas Henry Huxley

# Why may traits/ behaviors not be perfectly adapted?

- Failure of appropriate mutations to occur
- Single genes causing multiple phenotypic effects (pleiotropy)
  - One allele good for X trait but bad for Y trait
- Insufficient time / changing environment
- ... and many, many more



**Optimality** is the assumption that, by knowing how natural selection is acting on a trait, we can predict exactly what the trait should look like.

**Optimality predictions must be tested & judged, not presumed!**





# Example: Oxpecker

- Birds that live on large mammals, feed on ticks
  - Dogma that was repeated for many years: **mutualism**
- No good tests of it until ~2000.
- Explored whether cattle that had oxpeckers had **more/ less** ticks than cattle without oxpeckers

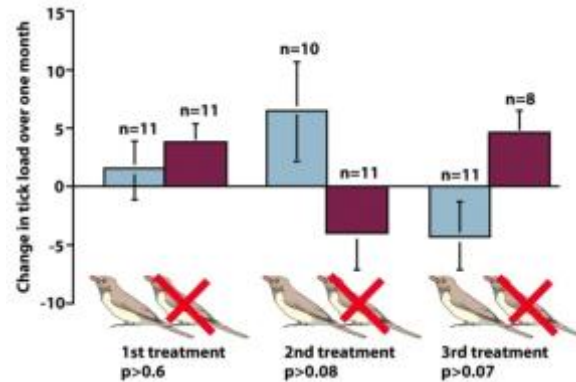






# Example: Oxpecker

- Test showed **no significant** reduction in tickload when had oxpeckers

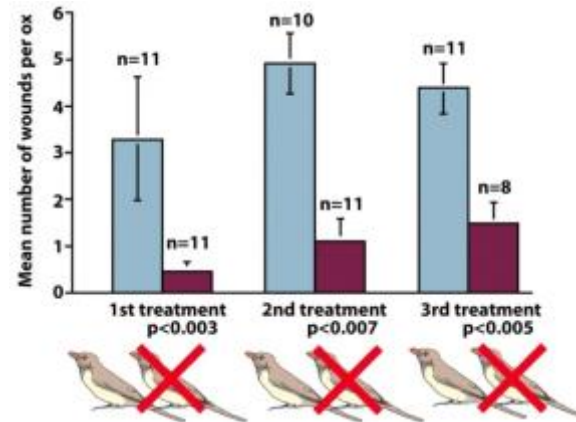
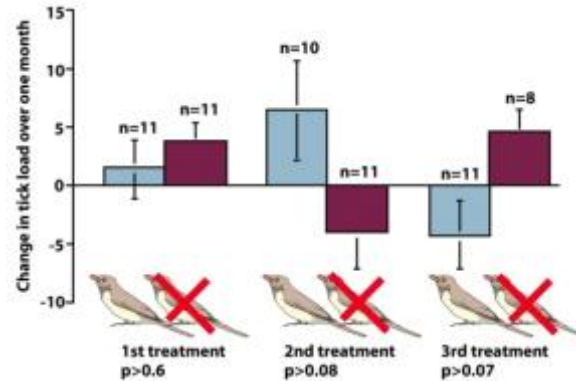






# Example: Oxpecker

- Test showed **no significant** reduction in tickload when had oxpeckers
- Further tests showed they actually enlarge open wounds and drink blood!



# But why do the hosts tolerate them?

## Class responses!

- Negative
  - The hosts don't tolerate the oxpeckers but just don't have the ability to keep them off.
- Neutral
  - It's like when a fly is buzzing in my face and after awhile, I just let it pester me because it won't go away.
- Advantage
  - They strengthen the cattle's immunity. In other words: increase in wounds = increase in small, non-fatal infection = increase antibodies to fight the antigens
- Out-there
  - Maybe they like the company!
  - Oxpeckers generate mini force fields the length of their wingspan that help the cattle's wounds feel better.



# But why do the hosts tolerate them?

## Research results

- Some of the hosts **try** to get them off - rhinos tried hard, but couldn't get them off *half* the time when they were at



wounds



Not at all the happy relationship assumed earlier!



# Topics

- Optimality theory
- Application to studying adaptive feeding behavior



# What considerations go into optimal feeding?

- Plus: calories from food (energy)
- Minus: energy for getting food
  - Energy used searching, energy used handling, energy used eating & digesting
- Minus: time involved getting food
  - Time for searching, time for handling, time for eating & digesting



# Optimal Foraging Formula

$$\frac{\text{Calories obtained from food} - \text{Calories expended getting food}}{\text{Time to get and eat food}}$$

- Want prey with highest caloric content
- Want to spend minimal energy getting prey
- Want to do this in as little time as possible



# Do whelk-eating crows feed adaptively?

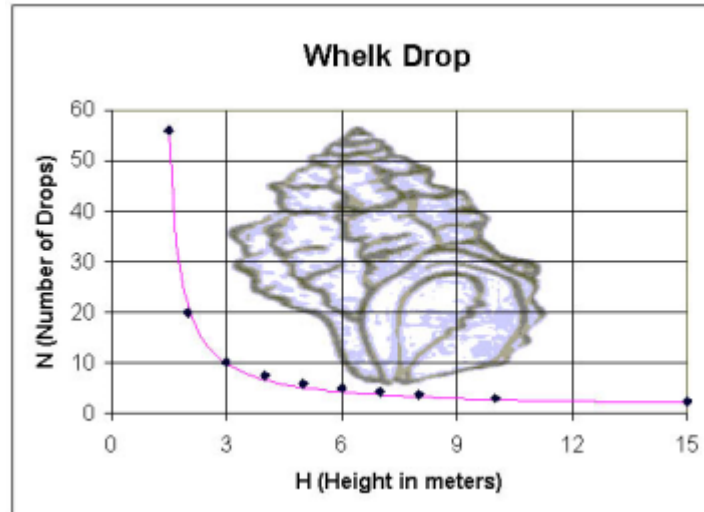
- Crows in British Columbia pick up whelks that are **4 cm long**—rarely less than that
- Fly up almost exactly **5 meters** and then drop to try to shatter and get snail meat
- Sometimes takes multiple flights to succeed
- Adaptive???





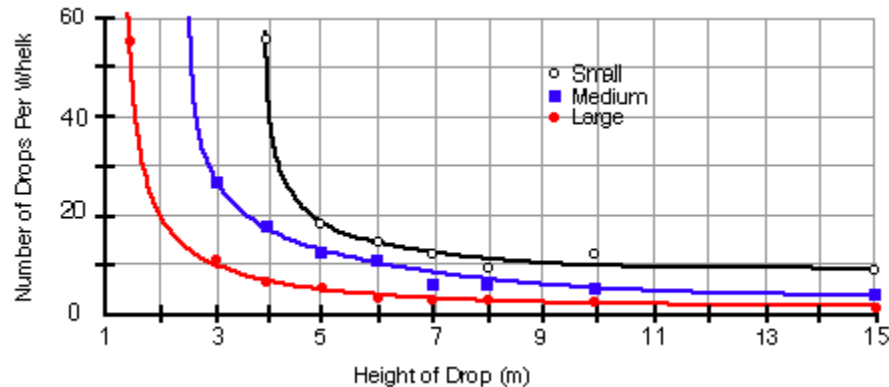
# Two parameters: 1) height of drop

- Takes energy to fly high- want to **minimize**
- BUT want high probability that shell will break
- Examination of the underlying physics:
  - **5m height is optimal** for the size shell they are choosing!
  - VERY little increase in probability of shell breaking higher



# Two parameters: 2) size of whelk

- Why not pick **smaller** whelk?
- Experimentally tried 3 sizes (4cm = large)
  - Found that need to fly higher and/ or drop more to break smaller whelk
  - Again, crows chose optimally!



# Do we see optimal feeding in humans? Case of *spices*

- Caloric content very low
- Why do we like them?
  - Random (or correlated response to other smell/ taste selection)
  - Direct selection
    - Antimicrobial property?



E. coli



# Many spices known to have antimicrobial properties

- Strong antimicrobial effectiveness in:
  - Cinnamon, cloves, mustard
- Medium antimicrobial effectiveness in:
  - Allspice, cumin, oregano, rosemary, sage, thyme
- Specific inhibitory effects:
  - Garlic: *Salmonella*, *E. coli*, *Staphylococcus*, *Bacillus*
  - Cloves: Mycotoxigenic *Aspergillus*



# Generate a prediction-

If spices are used because *antimicrobial*, and given what you may guess about whether the environments are warm/moist,

if we surveyed the following countries, which would you expect to use the most spices in their cuisine?

- \* India
- \* Hungary
- \* Norway



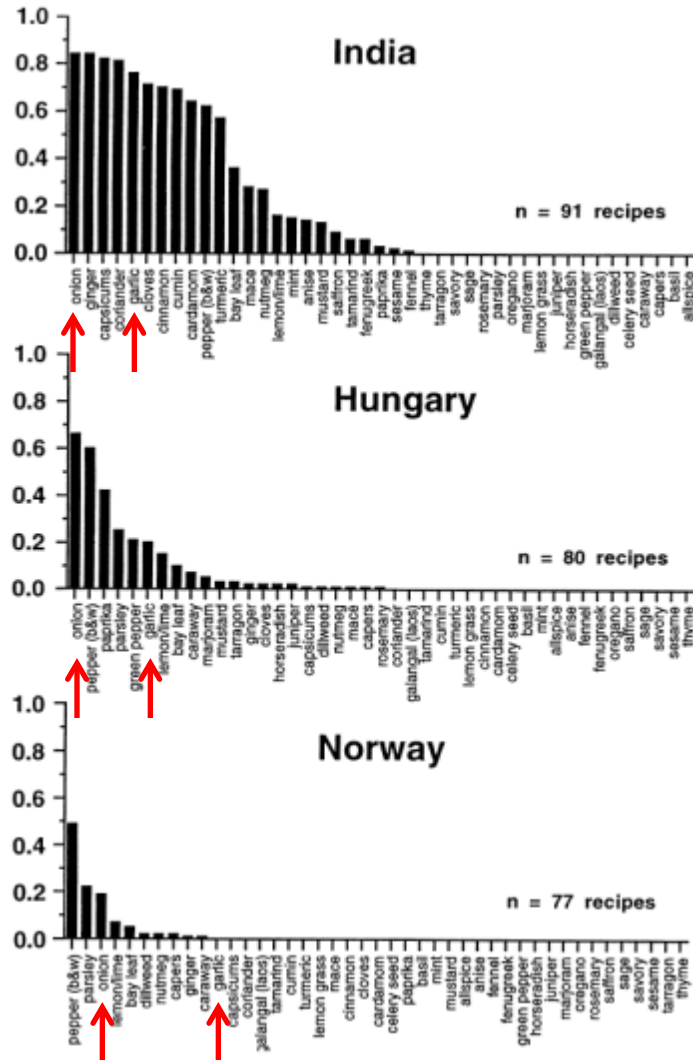
# Expectation:

- More antimicrobials needed in environments that favor growth of microbes

	Mean Temp	Mean Precipitation
• India	26.9 C	117.6cm
• Hungary	10.3 C	56.3cm
• Norway	2.8 C	96.0cm



# Spices used!

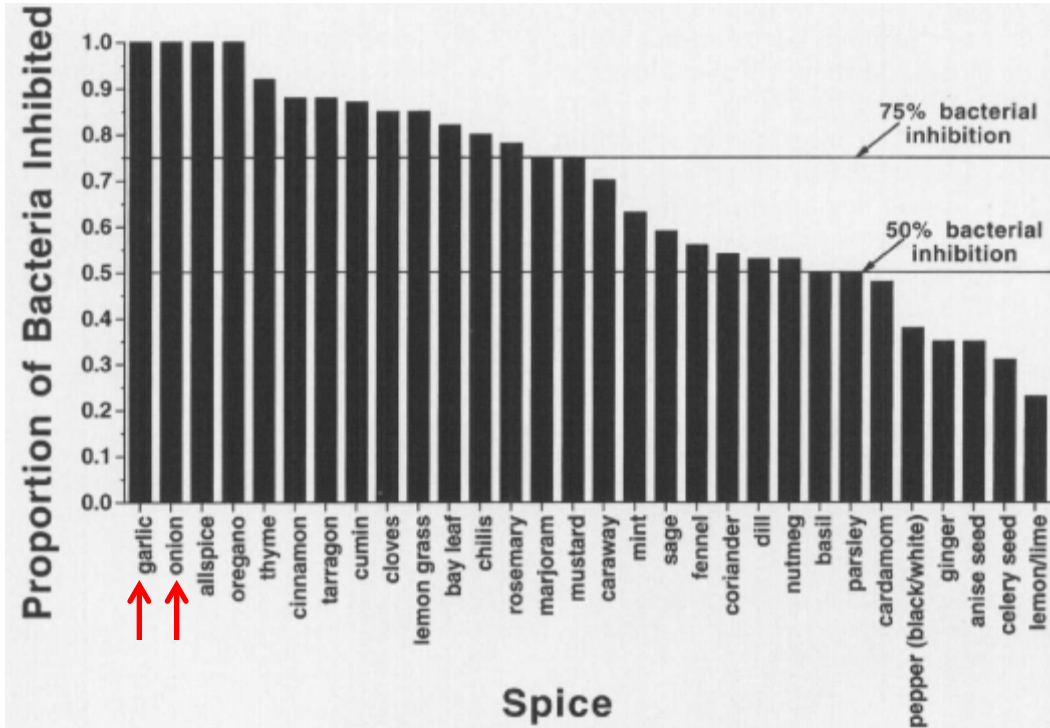


- WAY more spices used in Indian food than other two
- Red arrows designate use of garlic & onions in particular



# Antimicrobial effectiveness of spices

- Almost complete inhibition of bacteria by garlic and onions!



# Alternative explanations considered?

- Spices provide micronutrients
- Spices used to disguise smell of spoiled food
- Spices used where they grow



# Alternative explanations considered?

- Spices provide micronutrients
  - Doesn't explain correlation with temperature
- Spices used to disguise smell of spoiled food
  - Doesn't make sense evolutionarily
- Spices used where they grow
  - Very weak correlation between where they grow and where they are used
    - Pepper was one of most widely used and grows in very small fraction of the places tested



# Finding the best food: honeybee dances

Karl von Frisch  
Nobel laureate!



- Scout bees come back to hive and give hive mates detailed information about the location of food!
- <http://www.youtube.com/watch?v=-7ijl-g4jHg>



# How did people figure out the bee language?

- Answer:
  - Observation
  - Test using robot bees!

Video of robot bee in action:

[http://robobiene.mi.fu-berlin.de/videos/presentation\\_low.avi](http://robobiene.mi.fu-berlin.de/videos/presentation_low.avi)

More info:

<http://robobiene.mi.fu-berlin.de/pmwiki/pmwiki.php?n=Site.TheRobot>

See also: <http://abstrusegoose.com/a/186.htm> for an amusing (but crude) comic

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