Evolutionary medicine
Causes of disease can be viewed in two ways

1. **Proximate** - what and how physiological processes are involved in causing the disease and its symptoms

2. **Evolutionary** (ultimate) - why is a disease producing these effects
Medicine

• diagnosis and treatment of disease
• addresses the **what** and **how** questions
  **what** is causing the disease?
  **how** does the disease agent make you sick?
  **what** treatment will alleviate symptoms or heal you?
Evolutionary Medicine

• addresses the **why** questions

  *Why* is this disease agent causing this symptom rather than other symptoms?

  *Why* do injuries hurt?

  *Why* do animals senesce?

  *Why* do diseases exist at all?
Evolutionary medicine can improve treatment decisions

• Answers to why questions can help us understand the functional significance of symptoms
• Then more appropriate medical intervention can be made
Four categories of evolutionary explanations of disease

1. Defenses
2. Infection
3. Old genes in new environments
4. Design compromises
1. **Defenses** - often confused with other aspects of disease

- fever
- diarrhea
- morning sickness
Fever is an example of a symptom that can be a defense against pathogens

• elevated body temperature works to reduce the number of pathogens
Fever

- When infected with bacteria, desert iguanas choose places that are about ~2°C warmer than their normal preferred temperature.
What effect does fever reduction have on infection?

- 68 children infected with chicken pox
- acetomeniphen or placebo for 4 days
- placebo treated children recovered 1 day earlier
An odd example

1917 - Julius Wagner-Jauregg raised recovery rate for syphilis from 1% to 30% by a novel treatment

malaria
Fever can be an adaptive response to infection.
Diarrhea can be a defense against toxins. What happens when you take a drug to stop the diarrhea?
Diarrhea

- 25 volunteers had *Shigella* infection with diarrhea
- half were treated to reduce diarrhea
- half were given a placebo
• the half receiving the placebo (not treated) were feverish and ill half as long as those receiving drugs

= treatment prolonged the infection
Is morning sickness really a sickness,

• or a way to protect the fetus and mother from toxins or pathogens?
Nausea and vomiting peak 8-12th weeks. This is when fetus is most sensitive to chemical disturbance.

Figure 7. Nausea and vomiting tend to peak between the 8th and 12th weeks of pregnancy, which coincides with the peak sensitivity of various fetal tissues to a chemical disturbance.
Figure 9. Food aversions for various categories of foods (see Figure 8) differ across each trimester of pregnancy, being highest in the first trimester when the embryo is most sensitive to disruption.
• 7 studies show lower rates of miscarriage with NVP
• higher severity of NVP associate with lower rate of miscarriage
evolutionary perspective leads to questions…. 

- Do other mammals have it?
  Dogs, Rhesus monkeys, chimpanzees

- Do women in different cultures show different levels of sickness?
  Yes, and it is correlated with how much meat is in diet
Next category of evolutionary explanations of disease

2. **Infection** - the arms race between pathogens (bacteria and viruses) and our immune systems
Evolutionary Epidemiology

• how do disease characteristics change as hosts and parasites evolve in response to each other and their environments
In the arms race, on the evolutionary battlefield, between pathogens and us,

- microbes have a **huge** evolutionary advantage due to their short generation time
The number of generations microbes have in the span of one human generation boggles the mind.

So, the odds are against humans in an evolutionary race.
Which pathogens will be the most successful over evolutionary time?

• those that leave the most successful offspring
What is the relationship between virulence and success?
VIRULENCE

“decrease in host fitness by a pathogen”

• our assumption: increased virulence associated with pathogen doing more damage – or –

  using host quickly
Death of the host can be good, irrelevant or bad for the parasite, depending on the details.

When is it better to be more virulent and when is it better to less virulent?
High virulence makes a host very sick.

How can diseases be transmitted by pathogens in a very sick host?
host activity is not necessary for disease transmission.

- When pathogen transmitted by arthropods
- When pathogen transmitted by water supply or by caretakers
example: malaria

host doesn’t need to move and a very sick host maybe easier for mosquitoes to exploit
Lower virulence results in a more active host.

Active hosts can spread disease by direct contact. Example? A cold - a walking host spreads the pathogens around.
**evolutionary determinants of virulence**

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<thead>
<tr>
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<th>HIGH</th>
<th>LOW</th>
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<tbody>
<tr>
<td>mode of transmission</td>
<td>does not depend on active host</td>
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A second factor that can affect virulence is transmission rates.

High transmission rate = few contacts and short times required for successful transmission.
What happens if transmission rates can be cut?

- favor strains that keep host viable longer to increase chance of successful transmission
  = reduced virulence
Prediction: use of clean needles and condoms will favor the evolution of reduced virulence of HIV
# Evolutionary Determinants of Virulence

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<tr>
<td><strong>Mode of Transmission</strong></td>
<td>does not depend on active host</td>
<td>active host required</td>
</tr>
<tr>
<td><strong>Rates of Transmission</strong></td>
<td>few contacts necessary</td>
<td>many contacts necessary</td>
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Few contacts necessary for HIGH rates of transmission, whereas many contacts are necessary for LOW rates of transmission.
Four categories of evolutionary explanations of disease

3. Old genes in novel environments - recent changes in our environments, cause expression of previously unusual genotype x environment interactions
Our genes were molded by an environment that no longer exists.

- The first hominid lived ~ 6 million years ago.
- Agriculture-dominated civilization began about 15,000 years ago.
- Industrial revolution occurred about 100 years ago.
Individuals have genotypes and phenotypes

- organisms with the same genotypes can look different
- same genes work differently in different environments

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<tr>
<th>Species</th>
<th>Channel</th>
<th>Lagoon</th>
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<td><img src="lagoon_example.png" alt="Image" /></td>
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<tr>
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Which is more similar to the human digestive tract?

Actually falls between frugivore and carnivore
‘Recommended’ Diet vs. Paleolithic Diet
Compare again

- Protein
- Sucrose
- Fat
- Fiber
- Sodium

Source: Paleolithic Prescription by Eaton, Shostak, Konner, Harper & Row, 1988
Paleolithic diet

High in **LEAN meat** from game
- omega-3 fatty acid and provide iron, zinc, and vitamin B12
- saturated fat is still bad

High in **fiber** from wild plant foods
- no sign of cavities - brushed with dietary fiber
- lack of fiber in diet of growing children promotes crooked teeth
Earth cannot support 6 billion hunter-gatherers

BUT - Evolutionary perspective – new directions for investigation long term solutions
myopia (nearsightedness) is a genetic disease

25% of Americans have myopia

How could the hunter-gatherers from which we evolved have survived with such a bad gene?
native Americans in the Arctic had low rates of myopia until ….

contact with Europeans

led to children going to school …

which resulted in 25% myopia
how do eyes work and grow?

cornea and lens must focus image exactly on the retina

and do this while the eye is growing.....
how does an eye stay in focus as it grows?
research results

• an eye with an unfocused image view grows in length
• as the eye grows, corrections are made based on the quality of the image seen
• and growth stops when image is in focus
what an elegant mechanism

....except in the 25% of us that have
the ‘myopia gene’
myopia

proximate explanation

myopia is caused by excessive growth of the eye

excessive growth is caused by genes
gene x novel environment

• only recently have humans had to process such finely detailed images at such young ages
myopia

evolutionary explanation

a genetically determined mechanism regulates continued focus in growing eyes

some genetic variations cause excess growth when the eyes are used in frequent, close work when growing
gene x novel environment

many diseases may fall in this category:
  diabetes
  heart disease
  anxiety
  alcoholism
  dyslexia
4. Design compromises and evolutionary legacies

since evolution builds on previous designs, some features are not ideal
Choking

1/100,000 people die of choking each year
Choking

our food-pipe and our air-pipe cross

what advantage could this design possibly have? none
the design appears to be an evolutionary legacy

in fish, the mouth is used for both feeding and breathing
rearrangement of this area to allow speech make the problem worse
Evolutionary medicine can improve treatment decisions

- **Defenses**: Don’t work against symptoms that reflect your body’s weapons against disease or injury
- **Infection**: Change environment to favor low virulence of pathogens
- **Old genes/new contexts**: Alter current environment/behavior to reduce negative impact
- **Design compromises**: ?
(1) What was the most important thing you learned this week?

(2) What was least clear from lecture this week?