Evolutionary Medicine

Biol. 402-027Biol. 502-027

UNM Department of Biology Fall 2008

Castetter Room 104

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**Course description:**

The goal of this course is to understand how evolutionary biology provides insights into human health and disease. For most of the 20$^{th}$ century, the health sciences and evolutionary biology progressed along different paths, with neither discipline having much impact on the other. The last 15 years have seen increased exchange of information between the two fields of study. For instance, medical science has embraced evolutionary concepts that relate to pathogen antibiotic resistance. This course is a broader overview of evolutionary medicine. We will explore how natural selection influences pathogen-host interactions, human genetics, immunology, development, cancer, and diseases of senescence.

Evolutionary biology has important implications for the medical concepts of health, "normal" physiology and illness. One is the recognition of tradeoffs that sometimes promote health and other times result in illness. Many of these ideas challenge the conventional wisdom of the health sciences. During this course we will consider controversies and questions regarding health and evolution. A lecture will be given on each topic, and alternative hypotheses will be presented. Lectures will be followed by student-led discussion and critique of ideas in evolutionary medicine.

**Required Readings:**

A syllabus of required readings will be distributed on the first day of the course.

**Course Requirements & Grading:**

Students will be expected to attend all lectures. Students should complete assigned readings prior to that week's lecture and contribute to discussions. Each week, following lectures and discussions, students will be asked to complete a written summary of that week's topic. As a one-time assignment, students will be asked to evaluate the strengths and weaknesses of journal articles in evolutionary medicine. For this "Journal Club", a small group will be assigned a journal article to present to the group and provide commentary. Finally, each student will make a presentation during the last two weeks of the course. Students should choose an area that interests them and produce a brief talk (powerpoint or equivalent) to present to

the group.

Attendance and Participation. (35%)

Journal Club (10%)

Weekly Writing Project (20%)

Final Presentation (35%)

**Course Outline:**

**Week 1** - 8/25/08 - Introduction.

3:00pm - 4:00pm Evolution in Health and Disease– a new synthesis of medical science and evolutionary biology. (JA)

Levels of Analysis – differentiating between proximate "how" questions and ultimate "why" questions of human diseases.

4:00pm - 4:50pm Sickle Cell Disease and Malaria (JA) – One of the first evolutionary medicine hypotheses.

Readings:

1. Introduction and Overview of Evolutionary Medicine. Chapter 1 in: Evolutionary Medicine and Health. 2008. Trevathan WR, Smith EO, McKenna JJ. Page 1-54.

2. The Great Opportunity: Evolutionary applications to medicine and public health. Nesse, RM and Stearns SC. Evolutionary Applications 1 (2008) 28-48.

3. Two Lessons from the Interface of Genetics and Medicine. Allison A. Genetics 166: 1591–1599 (April 2004) (Read page 1-5)

Topics for discussion:

What is an example of a constraint in human physiology?

Give an example of how evolutionary conflict with pathogens can cause disease?

How do novel environments cause illness?

Give an example of how patients might benefit if doctors understand evolutionary biology

Writing project (due next session).

Explain why the incidence of sickle cell trait matches the geographic distribution of plasmodium falcuparum. Since sickle cell trait is common in the US and there is no malaria, what do you think will happen its incidence over time?

**Week 2** - 9/1/08 - Holiday

**Week 3** - - 9/8/08 - Adaptation to extreme environments. (JA)

3:00pm - 4:00pm Diving Illness. Disease as a mismatch between ancestral and modern environments.

Can some diseases be explained by new circumstances? Diving accidents as an example.

4:00pm - 4:50pm Mountain Sickness. Does the duration of experience affect how populations cope with environmental stress?

Sherpas, Andeans, Ethiopean Highlander's different adaptations to the high altitude environment.

Readings:

1. Evolution and the Origin of Disease. Nesse, RM. Scientific American November 1998: 86-93.

2. Three High Altitude Peoples, Three Adaptations to Thin Air. Hillary Mayell. National Geographic News. February 25, 2004.

3. Two routes to functional adaptation: Tibetan and Andean high altitude natives. Beall CM. PNAS May 2007 1:suppl 1(8655-8660).

Writing project: (due next session), pick one:

a) Explain what scuba diving and high altitude mountaineers have in common? Describe how gene-environment mismatch causes disease in the following: decompression illness, high altitude pulmonary edema.

b) Why doesn't everybody have perfect ability to cope with high altitude? What are some of the hardships and challenges (besides physiologic barriers) endured by human populations living at high altitude? Why do most humans live at low altitude?

c) How do psychoactive drugs cause disease by gene-environment mismatch?Do casinos exploit human neurobiology to extract money from your wallet? How is this gene-environment mismatch?

**Week 4** - 9/15/08 - Fever and Disease symptoms.

3:00pm - 4:00pm Evolution of Fever (BW)

Do symptoms represent host defenses or pathogen virulence factors?

4:00pm - 4:50pm Discussion (CE)

Topics for discussion:

How best to treat a cold?

Should physicians and nurses treat fever in the emergency room or clinic?

When should diarrhea be treated?

We give IV fluids to trauma victims in the ER. Is low blood pressure adaptive in trauma? How about infection?

Readings:

1. The adaptive value of fever. Kluger, MJ. et al. Infectious Disease Clinics North America. 1996.

2. Signs and Symptoms of infectious Disease. Chapter 3 in: Why We Get Sick, the New Science of Darwinian Medicine. Nesse RM, Williams GC. Times Books, Random House. 1st Ed. 1995. page 26-49.

Writing project (due next session):

Some illnesses make you feel bad, but you can still go about your business: e.g upper respiratory infections caused by rhinoviruses. Other infections wipe you out and you can't get out of bed. Is it in the rhinovirus's best interest to keep infected hosts in bed? What symptoms associated with common cold facilitate transmission of the virus? What is the best public health directive for colds: 1) go to work as usual. 2) go to the urgent care center for a work note. 3) stay at home.

**Week 5** - 9/22/08 – All Stings Considered.

3:00pm - 4:00pm Evolutionary Considerations of Venoms (JA)

What is the difference between a toxin and a venom?

Endotoxin and Jarisch Herxheimer reaction – toxin or host defense?

Can evolutionary medicine predict when antitoxins, immunotherapy, and vaccines to toxins will be effective?

Readings:

1. Toxins New, Old and Everywhere. Chapter 6 in Why We Get Sick, the New Science of Darwinian Medicine. Nesse RM, Williams GC. Times Books, Random House. 1st Ed. 1995. pages 77-90.

2. An evolutionary perspective of endotoxin: a signal for a well adapted defense system. Legrand EK. Med Hypotheses 1990. Sep; 33(1) 49-56.

3. Lipopolysaccharide: An Endotoxin or an Exogenous Hormone? Marshall JC. Clin

Infec. Dis. 2005:41 (Suppl 7). S470-80.

4:40pm Journal Articles for next weeks session will be assigned at this time. Journal article critique will take the place of the writing project for this week.

1. Carriership of Factor V Leiden and Evolutionary Selection Advantage. Lindqvist PG, Dahlback B. Cur Med Chem 2008. 15: 1541-1544.

2. Evolution and Hypertension. Weder AB. 2007; 49; 260-265.

3. Artificial lighting in the industrialized world: circadian disruption and breast cancer. Stevens RG. Cancer Causes Control (2006) 17:501–507

4. Bioactive properties of Plant Species Ingested by Chimpanzees. Krief S, et al. 2006. American Journal of Primatology 68:51-71

**Week 6** - 9/29/08 – Journal Club.

3:00pm - 4:00pm Student Journal Article Presentations

4:00pm - 4:50pm Discussion. Review of previous topics. Overview of evolutionary biology concepts and terminology. (CE)

**Week 7** - 10/6/08 – Vector-borne diseases and virulence

Guest Lecturer: Kathryn Hanley PhD.

3:00pm - 4:00pm Evolution of Virulence in Dengue fever. (KH)

4:00pm - 4:50pm Discussion (CE)

Questions for discussion:

Hospital Acquired Infections – are medical workers vectors of disease?

Do pathogens evolve toward commensalism?

How does the fact that much disease is attributable to host immune

response affect hypotheses about the evolution of virulence?

How might non-sterilizing (imperfect) vaccines impact the evolution of

virulence?

Readings:

1. Evolution of virulence. Ewald PW. 2004. Infect Dis Clin N Am (18) 1-15.

2. Epidemiology of Virulence. Galvani AP. 2003. TRENDS in Ecology and Evolution 18(3) 132-139.

3. How Virulent should a Parasite be to is Vector. Elliot SL, et al. 2003. Ecology 84 (10) 2568-2574.

4. Crossing the Line: Selection and Evolution of Virulence Traits. Brown NF et al. 2006. PLoS Pathogens. 2(5) e42. Pages 0346-0353

5. Global Spread and Persistence of Dengue. Kyle JL and Harris E. Annu Rev Microbiol. 2008. 62: pp 71-81.

Writing project (due next session)

Choose one:

a) Dengue fever immobilizes its adult victims. Does immobilization help or hurt the transmission of the virus? How is dengue different from the common cold?

b) Why do "hospital-acquired" infections get different antibiotics than "community acquired" infections. Which are generally worse and why?

**Week 8 -** 10/13/08 - Development - Cancer – natural selection and carcinogenesis.

Guest Lecturer: Stephanie Forrest PhD. Chair, UNM Computer Science Dept.

4:00pm - 4:50pm Discussion (CE)

Questions for discussion:

Does cancer break the cellular "social contract" required of multicellular organisms? If so why?

How do viruses cause cancer?

Readings:

1. Cancer as a microevolutionary process. Komarova NL and Wodarz D. Chapter 22 in: Evolution in Health and Disease. Second edition. Eds. Stearns SC and Koella JC. 2008. pages 289-299.

2. Human papillomavirus vaccine as a new way of preventing cervical cancer: a dream or the future. Mandic A. Vukoj T. 2004 Annals of Oncology 15: 197-200.

Writing project:

Cancers of the reproductive tract are very common, breast cancer in women, prostate cancer in men. What is it about the reproductive tract that might make it more susceptible to cancer?

**Week 9** -10/20/08 – Antimicrobial Resistance

Development of chloroquine resistance in falciparum malaria

Guest Lecturer: Roland Cooper PhD. Dept. Biology, Old Dominion University

4:00pm - 4:50pm  Discussion (CE)

Discussion topics:

What are the downsides of putting antibiotics into animal feed?

Is it smart science or smart business of pharmaceutical companies to try to market brand new antibiotics to physicians?

Readings:

1. Bergstrom CT & Feldgarden M. The ecology and evolution of antibiotic-resistant bacteria. Chapter 10 in: Evolution in Health and Disease. Second edition. Eds. Stearns SC and Koella JC. 2008. pages 125-137.

2. pfcrt is more than the Plasmodium falciparum chloroquine resistance gene: a functional and evolutionary perspective. Cooper RA, et al. 2005. Acta Tropica 94. pp 170-180.

3. Requiem for Chloroquine. Hastings IM, et al. 2002. Science 298. pages 74-75.

Writing project:

Plasmodium falciparum is an extremely difficult organism to eradicate and has developed resistance to most antimalarials. Explain why the way antimalarials are used might lead to resistance. Vaccine efforts have also failed. Come up with a hypothesis why it is harder to make a vaccine for a protozoan like plasmodium than for a bacterium like diptheria.

**Week 10** - 10/27/08 – Evolution of Emerging Diseases

Guest lecturer Greg Ebel DSc. UNM Pathology Dept.

Vector traits and host switching in the evolution of West Nile Virus in North America

For discussion (CE):

What accounts for the rapid spread of West Nile Virus in North America?

So why isn't HIV transmitted by mosquitos?

Can we alter the evolution of microbes with medical interventions or public health measures?

Readings:

1. Emergence of new infectious diseases. Woolhouse M and Antia R. Chapter 16 in:

Evolution in Health and Disease. Second edition. Eds. Stearns SC and Koella JC. 2008. pages 215-252.

Writing project:

Some new diseases jump ship from animal hosts to humans, like SARS from civet cats, Ebola virus from monkeys. Come up with a hypothesis for why epidemics of SARS and Ebola burned out and new cases disappeared after a short time.

**Week 11** - 11/3/08 – Reproduction.

3:00pm - 4:00

Evolutionary considerations of pregnancy and human childbirth

4:00pm - 4:50pm Discussion (CE)

Questions for Discussion:

Morning Sickness – why does it occur; does it have a benefit to the fetus or mother?

Menopause – why do women cease to reproduce in middle age?

Readings:

1. Evolution of the human menopause. Shanley DP and Kirkwwod TB. 2001 Bioessays 23. 282-287.

2. Nausea and vomiting of pregnancy in an evolutionary perspective. Sherman PW, Flaxman SM. 2002. Am J Obstet Gynecol 186:S190-7.

3. Evolutionary Obstetrics. Trevathan WR. Chapter 8 in in Evolutionary Medicine (1st edition) 1999. Eds Trevathan WR, Smith EO, McKenna JJ. Oxford University Press. pages 183-207.

Writing project:

Some suggest that menopause evolved because grandmothers are more successful at passing on their genes by investing in grandchildren than in more babies of their own. Others argue that menopause is a consequence of modern medicine prolonging the lifespan of women past 60 when most pre-historic women would be dead. So in the past reproductive aging would have been in sync with aging of the rest of the body. In this view menopause reflects the early mortality in pre-history and is a gene-environment mismatch. There is evidence for and against both the "grandmother hypothesis" and the "artificial lifespan prolongation" hypothesis. Argue for or against either in your paper.

Extra credit: Hormone replacement therapy. Is menopause a treatable deficiency disease? Write about the pros and cons of hormone replacement therapy from an evolutionary point of view. under which hypothesis, "grandmother" or "artificial

lifespan prolongation" would you predict that HRT would be more helpful in promoting heath and preventing disease. What does the data say? (This will take some research.)

**Week 12** - 11/10/08 –Parent Offspring Conflict.

3:00pm - 4:00pm Genomic imprinting and conflicts (JA)

Do genes derived from maternal or parental sources have different effects on offspring?

Gestational diabetes – a paternal gene effect?

Pre-ecclampsia – what effect does blood pressure have on the placenta and vice-versa?

4:00pm - 4:50pm Discussion (CE)

Topics for Discussion:

Why would exposure to sperm decrease the incidence of preeclampsia?

Why should spontaneous abortions and preeclampsia have the same risk factors?

Should donor-egg IVF recipients be warned about the risk of preeclampsia?

Should sperm donors be held responsible for preeclampsia induced by their sperm?

Readings:

1. Ness RB and Grainger DA, et al. Male reproductive proteins and reproductive outcomes. Am J Obstet Gynecol 2008;198:620.e1-620.e4.

2. Haig D. Genetic Conflicts in Pregnancy. Quarterly Review of biology. Volume 68 (4). Dec 1993, 495-532.

Writing project:

Some have suggested that the age of weaning of infants from the breast is subject to parent offspring conflict. Eg. infants might want to breastfeed longer than the mother would like. Breastfeeding tends to suppress ovulation and delay pregnancy. Give an evolutionary hypothesis for why infants might exhibit behavior that promotes longer breastfeeding. What behaviors might these be? The infant has 1/2 maternal derived genes and 1/2 paternal derived genes; which of these would these be expected to prolong breastfeeding?

**Week 13** - 11/17/08 – Cardiovascular Disease (JA)

3:00pm - 4:00pm. Thrifty Genotype and Thrifty Phenotype (JA)

Developmental tradeoffs in an uncertain world.

Does stress in pregnancy affect likelihood of children to get diabetes and heart disease?

4:00pm - 4:50pm  Diet, Obesity and Evolution (JA)

Are we healthiest when eating what our ancestors ate?

Why are we all so fat?

Topics for discussion:

Why does obesity cause disease?

Readings:

1. The Developmental Origins of Adult Health. Kuzawa C. Chapter 18 in Evolutionary Medicine and Health. 2008. Trevathan WR, Smith EO, McKenna JJ. pages 325-349.

Writing project:

There appears to be  switch activated in underweight babies that leads to diabetes later in life. Early on, these individuals might be insulin resistant - so less glucose gets metabolized by muscle tissue. As a result, less energy is devoted to growth and building muscles and bones. On the flip side, more glucose is available for other tissues - like the brain and also infection fighting cells. Come up with a hypothesis for how insulin resistance might be helpful for underweight neonates?

**Week 14** - 11/24/08 –  Allergy & Worms. (JA)

3:00pm - 4:00pm. Hygiene hypothesis (JA)

Exposure to parasite antigens might be necessary for appropriate activation of IgE arm of immune system.

Do people with parasites have allergies?

4:00pm - 4:50pm  Discussion and Presentations (CE)

Questions for discussion:

Should all children be sent to the third world or the country farm?

Why is it so hard to develop a vaccine against protozoa and helminths?

Readings:

1. Pig worms and multiple sclerosis: the unintended consequences of hygiene. Sterns S. July 10, 2008. and comment: Microbes Evolution and Chronic Inflammatory Disorders. Rock G. July 14, 2008. The Evolution and Medicine Review,

Blog Archive.

2. Scientist at Work. The worms crawl in. New York Times July 1, 2008.

No writing project this time. Work on your presentations!

**Week 15 -**12/1/08 – Aging

3:00pm - 4:00pm. Why we get old (JA)

Declining power of selection – does natural selection keep post-reproductive people alive?

Antagonistic pleiotropy – do genes that promote youthful health also cause disease in the elderly?

Disposable Soma hypothesis.

4:00-4:50pm Discussion and Presentations (CE)

Topics for discussion:

How might antagonistic pleiotropy cause heart attacks?

Readings:

1. Still Pondering an Age-Old Question. Flatt T and Promislow EL. 2007. Science (318) 1255-1256.

**Week 16**, 12/8/08 - Presentations