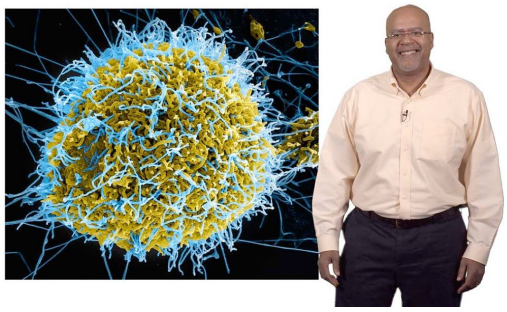
Session 10: Viral evolution

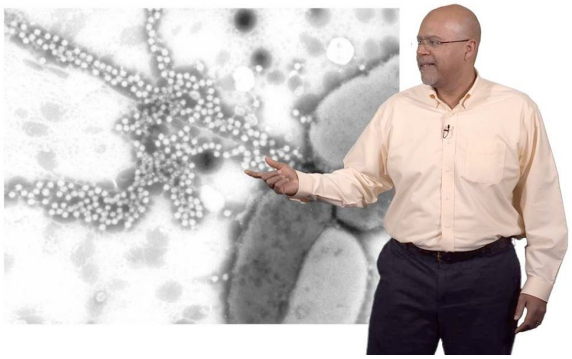
Overview:
Although we tend to think of evolution as something that happens slowly and over long periods of time, it is actually happening around us all the time. In this session, Drs. Turner and Malik focus on the ability of viruses to rapidly evolve and adapt to changing environments. Turner explains how some viruses have evolved to infect many hosts while others infect a single cell type. He also uses experimental evolution to study the ability of a virus to survive under different environmental conditions versus its ability to effectively reproduce. Malik studies the ongoing battle between viruses and their hosts and describes some of the tricks each use to survive attacks by the other.

Optional Video: Introduction to Virus Ecology and Evolution
Speaker: Paul E. Turner



First video:
Title: Virus Adaptation to Environmental Change
Speaker: Paul E. Turner

Please watch this video from time 4:45 to 43:36.



Questions for Part 1:

1. Which of the following problems may viruses face when they adapt to a new environment or host?
    a. Viruses have a high rate of mutation.
    b. Viruses cannot adapt fast enough to new environments.
    c. Mutations in housekeeping genes are not well tolerated.
    d. Like bacteria, it's hard for viruses to adapt to a new host.
    e. None of the above.

2. Choose all of the answers that apply. The HIV is an example of
    a. A generalist virus.
    b. A specialist virus.
    c. A DNA virus.
    d. An RNA virus.
    e. None of the above.

For questions 3-6, determine if the statement is true or false. If the statement is false, change one word to make it true.

3. Viruses that have high reproductive success show increased survival to environmental change.

4. When the phi-6 virus is confronted with high temperatures, it evolves a mutation that makes the P5 protein more unstable at high temperatures.

5. Viruses that have evolved to infect many hosts species can easily infect new species.

6. Viruses have shaped the evolutionary history of humans and you can find evidence of this in human DNA.

7. The dengue virus can infect humans as well as other species.
    a. Is dengue a generalist or a specialist virus?

    b. What properties allow viruses to infect diverse species? Briefly explain.

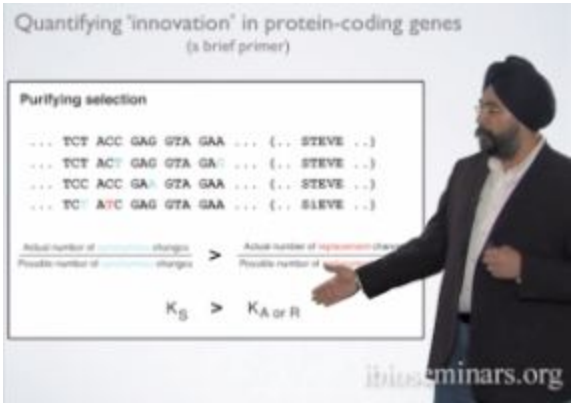
8. AZT is a drug that was developed to treat patients with HIV. Although initially effective, different strains of HIV evolved resistance to AZT.
    a. Scientists observed the same mutations in the different strains with resistance to AZT. Propose an explanation for this observation. Which viral proteins are most likely to evolve adaptive mutations?

    b. AZT kills HIV but it also has serious side effect for humans. Why might this happen?

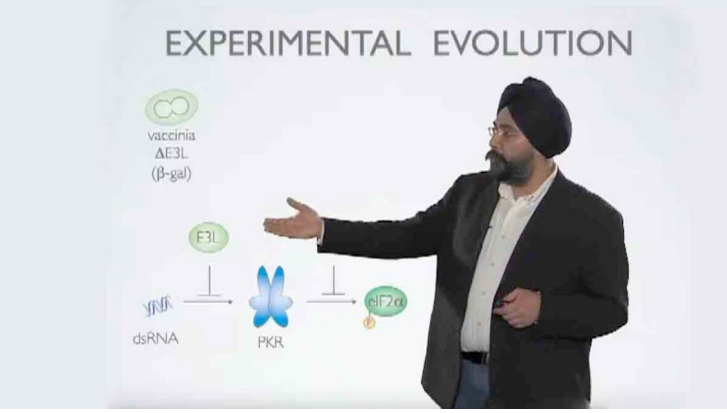
9. Briefly explain why viruses that evolve to survive extreme temperatures show lower reproductive success.

Second video:
Title: Host evolution
Speaker: Harmit Malik

Please watch this video from time 00:00 to 21:10.



Third video:
Speaker: Harmit Malik
Title: Viral evolution



Questions for Part 2 and 3:

1. The HIV and dengue viruses infect different types of cells because
    a. A virus generally does not infect cells that other viruses infect.
    b. The HIV virus binds to specific receptors present only on T cells.
    c. The dengue can infect T-cells, but only during late stages of infection.
    d. They are both RNA viruses.
    e. None of the above.

2. Which of the following methods do viruses use to circumvent the Protein Kinase R (PKR) pathway? Choose all of the answers that apply.
    a. Hiding the viral genome.
    b. Increase production of viral proteins in a eIF2alpha-independent manner.
    c. Blocking dimerization events in the PKR pathway.
    d. Phosphorylation of the ribosomes.
    e. None of the above.

3. Which of the characteristics of malaria, listed below, reflect the evolution of mechanisms to evade the host immune system? Choose all of the answers that apply.
    a. Malaria is transmitted by an insect vector.
    b. Malaria has a nucleus and membrane-bound organelles.
    c. Malaria produces proteins.
    d. Malaria shows antigenic variation in its cell-surface proteins.
    e. None of the above.

For questions 4-7, determine if the statement is true or false. If the statement is false, change one word to make it true.

4. Viruses can mimic host proteins in order to hijack host defense mechanisms.

5. Protein Kinase R has undergone strong evolutionary pressure because multiple viruses have targeted this protein as part of their infection process.

6. Diversifying selection is frequently observed in genes involved in metabolism.

7. The viruses and their hosts are in a static evolutionary battle for survival.

8. Viruses use host proteins for infection and replication. In response, host proteins can evolve mutations that block interactions with the virus and help to prevent infection. However, the ability of the host to constantly mutate its proteins is limited. Provide two reasons why this is true.

9. Viruses have different mechanisms to evolve in response to environmental changes. Briefly explain how viruses use the following mechanisms to improve fitness.
    a. Duplication events

    b. Mutations

Answers for Session 10:

Questions for Part 1:

1. Which of the following problems may viruses face when they adapt to a new environment or host?
    a. Viruses have a high rate of mutation.
    b. Viruses cannot adapt fast enough to new environments.
    c. Mutations in housekeeping genes are not well tolerated.
    d. Like bacteria, it's hard for viruses to adapt to a new host.
    e. None of the above.

2. Choose all of the answers that apply. The HIV is an example of
    a. A generalist virus.
    b. A specialist virus.
    c. A DNA virus.
    d. An RNA virus.
    e. None of the above.

For questions 3-6, determine if the statement is true or false. If the statement is false, change one word to make it true.

3. Viruses that have high reproductive success show increased survival to environmental change.
    False; ~~high~~ low

4. When the phi-6 virus is confronted with high temperatures, it evolves a mutation that makes the P5 protein more unstable at high temperatures.
    False; ~~unstable~~ stable

5. Viruses that have evolved to infect many hosts species can easily infect new species.
    True.

6. Viruses have shaped the evolutionary history of humans and you can find evidence of this in human DNA.
    True.

7. The dengue virus can infect humans as well as other species.
    a. Is dengue a generalist or a specialist virus?
    A generalist.

    b. What properties allow viruses to infect diverse species? Briefly explain.
    Generalist viruses inhibit the innate immune response of host cells by inactivating proteins that are common to this response across species and cell types.

8. AZT is a drug that was developed to treat patients with HIV. Although initially effective, different strains of HIV evolved resistance to AZT.
    a. Scientists observed the same mutations in the different strains with resistance to AZT. Propose an explanation for this observation. Which viral proteins are most likely to evolve adaptive mutations?
    Convergent evolution. If a mutation confers resistance to AZT, allowing the virus to survive, selection for this mutation will be strong across HIV strains. Therefore, different stains will evolve to have the same advantageous mutation. The mutations are likely to occur in the viral protein that interacts with AZT. The mutation may prevent AZT binding without interfering with the original function of the protein.

    b. AZT kills HIV but it also has serious side effect for humans. Why might this happen?
    AZT likely binds to and inhibits both a viral protein and a human protein.

9. Briefly explain why viruses that evolve to survive extreme temperatures show lower reproductive success.
    Viruses (and cells) can invest resources in either survival or reproductive success but not both at the same time. There is an indirect correlation between rate of mortality and rate of multiplication.

Questions for Part 2 and 3:

1. The HIV and dengue viruses infect different types of cells because
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    c. The dengue can infect T-cells, but only during late stages of infection.
    d. They are both RNA viruses.
    e. They are both DNA viruses.

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    a. Malaria is transmitted by an insect vector.
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    d. **Malaria shows antigenic variation in its cell-surface proteins.**
    e. None of the above.

For questions 4-7, determine if the statement is true or false. If the statement is false, change one word to make it true.

4. Viruses can mimic host proteins in order to hijack host defense mechanisms.
   True.

5. Protein Kinase R has undergone strong evolutionary pressure because multiple viruses have targeted this protein as part of their infection process.
   True.

6. Diversifying selection is frequently observed in genes involved in metabolism.
   False; ~~metabolism~~ immune system.

7. The viruses and their hosts are in a static evolutionary battle for survival.
   False; ~~static~~ continuous

8. Viruses use host proteins for infection and replication. In response, host proteins can evolve mutations that block interactions with the virus and help to prevent infection. However, the ability of the host to constantly mutate its proteins is limited. Provide two reasons why this is true.
   a. **The virus can also adapt. Compensatory mutation in the virus can follow mutations in host proteins.**
   b. **The virus may interact with host housekeeping proteins. Some of these proteins are crucial for host survival. Too many mutations may inhibit the protein function which would be detrimental to the host as well as the virus.**

9. Viruses have different mechanisms to evolve in response to environmental changes. Briefly explain how viruses use the following mechanisms to improve fitness.
   a. Duplication events
      Duplication events allow the virus to generate potential new proteins. These proteins could be acted upon by pressures that eventually would select for proteins that have mutated to improve fitness in the new environment.

   b. Mutations
      Classical Darwinian adaptation model. Mutations that improve infection, replication or survival will improve viral fitness.