This Presentation covers the following:

- Information About Malaria
- Evolution & History
- Etiology, Host Specific Parasites & Transmission
- Symptoms & Pathology (Human)
- Treatments (Human)

Questions?

- What is Malaria?
- How many people think Malaria is caused by mosquitoes?

Figure 1: A mosquito (Picture courtesy of Wellcome Library, London)
**Terminology**

- Anemia - decrease in number of red blood cells and/or quantity of hemoglobin.
- Erythrocytic schizogony - the process of asexual reproduction of malaria parasites within red blood cells.
- Exerythrocytic schizogony - the process of asexual reproduction of malaria parasites outside of red blood cells, usually in the liver.
- Macro-gametocyte - the female form of the gametocyte.
- Microgametocyte - the male form of the gametocyte.
- Anthropophilic: mosquitoes that prefer to take blood meals on humans.
- Endemic: Where disease occurs on a consistent basis.
- Endophagic: is a mosquito that feeds indoors.
- Endophilic: is a mosquito that tends to inhabit/rest indoors.

**Information**

- Caused by protozoan parasites
- Vector borne infectious disease
- Very common infectious disease
- Transmitted by female *Anopheles* mosquito

**Malaria World Wide**

- 40% of the world's population live in areas where malaria is transmitted
- 300-500 million clinical cases of malaria occur each year
- 1.5-2.7 million people die from malaria each year
- Pregnant women and infants have high death rates
- Child dies every 30 seconds
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Deaths Caused by Malaria

Table 4. Leading causes of death 2000-03 (WHO, 2005)

<table>
<thead>
<tr>
<th>Cause</th>
<th>Number</th>
<th>% of total deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaria</td>
<td>3,915</td>
<td>17</td>
</tr>
<tr>
<td>Acute respiratory infections</td>
<td>2,077</td>
<td>8</td>
</tr>
<tr>
<td>Diarrhea</td>
<td>1,762</td>
<td>7</td>
</tr>
<tr>
<td>Malaria</td>
<td>632</td>
<td>2</td>
</tr>
<tr>
<td>Other causes</td>
<td>92</td>
<td>4</td>
</tr>
<tr>
<td>Other causes</td>
<td>1,922</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>12,306</td>
<td>100</td>
</tr>
</tbody>
</table>

Figure 4. Geological Time Scale (University of Waikato)
Term “malaria” derived from the Italian word mala = “bad” aria=“air”

The disease was formerly called ague or marsh fever due to its association with swamps.

Originated in Africa

30 mya fossilized mosquito proves the presences of vectors in early history

10,000 years ago malaria parasite caused major impact on humans

Three people were awarded the Nobel Prize for work associated with malaria.

Information About Malaria

Evolution & History

Etiology, Host Specific Parasites & Transmission

Symptoms & Pathology (Human)

Treatments (Human)
The Host of *Plasmodium*

- Birds
- Reptile
- Rodents
- Monkeys
- Apes
- Humans

**Taxonomic Classification & Anatomy Of Plasmodium**

- Kingdom: Protista
- Phylum: Apicomplexa
- Class: Sporozoasida
- Order: Haemosporida
- Family: Plasmodiidae
- Genus: *Plasmodium*

**Invasion of Erythrocyte**

- Figure 7: Anopheles mosquito in flight after a blood meal. This image is by Hugh Sturrock of the University of Edinburgh. 5/11/2009

- Figure 8: *Plasmodium* Anatomy (Columbia University)

- Figure 9: A further advanced stage of erythrocyte (E) entry by a merozoite (Mz). The junction (C) is now located at the posterior end of the merozoite and is moving toward the posterior end of the erythrocyte (Aikawa et al. 1978)

- Figure 10: Erythrocyte (E) entry by a merozoite (Mz) is almost completed and a small orifice (arrow) is seen at the posterior end of the merozoite. The junction (C) is now located at the posterior end of the erythrocyte (Aikawa et al. 1978)
Figure 11. P. falciparum binds to Endothelial cell to avoid being detected by host immune system. (Cooke, 2000)

The presence of large quantities of parasite material in the blood triggers a dramatic immune response (Hommel & Gilles 1998)

Production of cytokines can have pathological consequences (Richards 1997)

In pregnant women, P. falciparum frequently isolates itself in the placenta.

Four Species of *Plasmodium* which infect humans and cause malaria

- Plasmodium vivax
- Plasmodium falciparum
- Plasmodium malariae
- Plasmodium ovale
There are about 430 Anopheles species & only 30-40 transmit malaria.

Transmitted by female Anopheles mosquito (Definitive host).

Salivary Gland

Life cycle

Impact on Anopheles mosquito by the malaria parasites.

Anopheles (Vectors)

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Figure 13. Anopheles Female (Top) Male (Middle) Adult (Bottom). Note the typical resting position. (CDC)

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Figure 14. Drawing of a mosquito representing two salivary glands (P) and the proboscis. (Frischknecht et al. 2004.)

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Figure 15. Malarial sporozoites in mosquito salivary gland smear. (BIDDACO/ Houseman)

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Life Cycle of Plasmodium

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Figure 16. Life cycle of plasmodium from mosquitoes to host and back.
Malaria Species

Table 2. Four different types of plasmodium species and their unique characteristics during the life cycle. (John Hopkins S.P.H)

<table>
<thead>
<tr>
<th>Plasmodium Species</th>
<th>P. falciparum</th>
<th>P. vivax</th>
<th>P. ovale</th>
<th>P. malariae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hepatic Development Phase</td>
<td>0-15</td>
<td>2-4</td>
<td>2-4</td>
<td>0-15</td>
</tr>
<tr>
<td>Cytocerebrocytic Cycle (days)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Hypoanemia</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Microscopic per schizont</td>
<td>10,000</td>
<td>10,000</td>
<td>15,000</td>
<td>2,000</td>
</tr>
<tr>
<td>N.B. preference</td>
<td>All polymorphonuclear</td>
<td>Reticulo</td>
<td>Reticulo</td>
<td>Older RBC's</td>
</tr>
</tbody>
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Common Symptoms
- Fever, chills, arthralgia (joint pain), vomiting and anemia.
- Paroxysms: Sudden Attack
  - Last up to 10 or 12 hours
  - Divided into 3 stages
    1. Cold Stage
    2. Hot Stage
    3. Sweating Stage

Figure 17. Symptoms caused by Plasmodium species (CDC)

Clinical Complications of Malaria

P. falciparum
1. Central nervous system
2. Anemia
3. Pulmonary edema
4. Renal failure
5. Lactic acidosis
6. Metastatic infection
7. Hepatic failure
8. Pregnancy
9. Malaria death
10. Lactic acidosis
11. Anemia

P. vivax
1. Renal insufficiency
2. Hematologic syndrome leading to nephrotic syndrome

P. ovale

P. malariae
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Treatments

- Medicinal Treatment
  - Anti-malarial drugs
  - Intravenous infusion
  - Suppository

- Preventive Methods
  - Vector Control
  - Sharing of needles
  - Blood screening

- Genetic Response
  - Premonition
  - Sickle Cell
  - Favism-G6PD
  - Ovalocytosis
  - Alpha-thalassemia

Figure 18. Stages of paroxysm (John Hopkins SPH)

Figure 19. Bed nets treated with insecticides (CDC)

Figure 20. Sickle Cell (Uni. Michigan)
Conclusion

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Literature Cited

- Centers for Disease Control and Prevention. 11 May 2009 <http://www.cdc.gov/>,