Medical Parasitology

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Definitive (final) host harbors adult or sexually reproductive stage of a parasite.

Intermediate host: harbors larval or asexually reproductive stage of a parasite, according to priority they are classified into first intermediate host, second intermediate host, third intermediate host.

Reservoir hosts: It is the habitat where an infectious agent is naturally found, grows, multiplies and where it does not cause illness or disease.
Zoonosis: refers to animal’s diseases which can be transmitted to man.

Life cycle is the process of a parasite’s growth, development and reproduction, which proceeds in one or more different hosts depending on the species of parasites.

Infective Stage: is a stage when a parasite can invade human body and live in it.

A parasite which lives in the body of the host is called Endoparasite (protozoa and helminthes) or on the body of the host is called Ectoparasite (arthropods)
A parasite: is an organism that live on or within another organism (host). it is the benefited partner.

Host: In parasitism, it supplies the parasite with nourishment and shelter, it is the injured partner.

Carrier: A person who harbours parasite has no clinical symptoms, is an important source of infection in epidemiology.
• **Alternation of Generation:** In life cycles of some parasites, there are regular alternations of sexual and asexual reproductions.

• **Mechanical Transmission:** Arthropods play a role of the transportation of pathogens, such as flies carry typhoid bacilli, ascars eggs and amoebic cysts.

• **Biological Transmission:** Pathogens have to spend a part of their life cycle in the vector arthropods in which they multiply or develop into the infective stage and then invade the human body under the help of the arthropod.
Pathogenicity of parasites

• **Mechanical effects of parasites on host tissues and organs:** e.g. Ascaris Perforate/Obstruction

• **Depriving nourishment from hosts:** e.g. Hookworm Suck blood and cause anemia

• **Toxic effect:** e.g. Entamoeba histolytica Proteolytic enzyme that leads to Necrosis.

• **Immuno-pathological lesion** e.g. Schistosoma liver cirrhosis; when hydatid fluid is released from the rupture of a hydatid cyst anaphylaxis often results.
Human Immunity against Parasites

• Immune intensity and specificity are usually at a lower level than those produced by bacteria and viruses.

• Parasitic infection often trigger an inflammatory response in which Eosinophils, Basophils, and other specialized granules containing cells release their stores of toxic chemicals in an attempt to destroy in invaders.

• Antibodies also play a role in this attack, attracting the granule-filled cells to the site of infection.
Two major groups will be considered:

1. **Protozoa**: unicellular eukaryotes. Classifying into four taxonomic groups is based on their: **means of locomotion**, and **mode of reproduction**.

   - **A. Flagellates**: Three of the most common and medically significant include: *Giardia lamblia*, *Trypanosome sp.* and *Trichomonas vaginalis*

   - **B. Aamebae**: Amoeba –include the pathogenic amoeba *Entamoeba* and *Endolimax* which cause dysentery in humans

   - **C. Sporozoa**: The Sporozoa are protozoans that lack locomotion organs. They have no cilia, no flagella, no pseudopods. At some state in their life histories, they are usually intracellular parasites. e.g. *Malaria*

   - **Ciliates**: The only parasitic ciliate that causes disease in humans in *Balantidium coli*
Diversity among Protozoa

I. Amoebas
- Radiolarian
- Pseudopod
- Amoeba
- Foraminiferan

II. Flagellates
- Trypanosoma
- Trichomonas
- Flagellum
- Euglena

III. Ciliates
- Cilia
- Balanidium
- Paramecium

IV. Apicomplexans (Sporozoa)
- Plasmodium in red blood cells
- Babesia in red blood cells
2. **Helminthes** (worm of humans): belong to two phyla:

1. **Nematoda (Roundworms)**

2. **Platyhelminthes (Flatworms)**, are hermaphroditic, with a few exceptions. Platyhelminthes species are belong to two classes:

   A. **Trematoda (Flukes)**

   B. **Cestoda (Tapeworms)**.

3. **Arthropods**
Protozoa

A. Intestinal protozoa
   Giardia lamblia (flagellate), Entamoeba histolytica (ameba), Cryptosporidium hominis (sporozoa)

B. Sexually transmitted protozoan infection
   Trichomonas vaginalis (flagellate)

C. Blood and tissue protozoan infections
   Leishmanis, Trypanosoma
Routes by which humans acquire parasitic infections

**Contact and Penetration of Eyes**
- Acanthamoeba

**Vector-Borne**
- Kissing bug: *Trypanosoma*
- Mosquito: *Plasmodium*, *Wuchereria*
- Sand fly: *Leishmania*
- Tsetse fly: *Trypanosoma*

**Inhalation**
- *Acanthamoeba*
- *Enterobius*
- *Naegleria*

**Fecal-Oral, Ingestion**
- *Ascaris*
- *Balantidium*
- *Cryptosporidium*
- *Cyclospora*
- *Echinococcus*
- *Entamoeba*
- *Enterobius*
- *Fasciola*
- *Giardia*
- *Taenia*
- *Toxoplasma*

**Contact and Penetration of Skin**
- *Ancylostoma*
- *Necator*
- *Schistosoma*

**Sexual Contact**
- *Entamoeba*
- *Giardia*
- *Trichomonas*
Amoeba

- Protozoa with no truly defined shape
- Move and acquire food through the use of pseudopodia
- Found in water sources throughout the world

• **Entamoeba histolytica**
  – Amoebic dysentery

• **Naegleria**
  – primary amoebic meningoencephalitis

• **Acanthamoeba**
  – contact lens contaminant
Entamoeba histolytica

• Carried asymptotically in the digestive tracts of humans
• No animal reservoir exists
• Infection usually occurs by drinking water and food contaminated with feces that contain the cysts
• In the small intestine, converted to trophozoite and migrate to the large intestine where they multiply.
• Cysts (infective), only exist outside the host. They are round and usually 10-15 micrometers in diameter. They are non-motile and surrounded by a chitin wall that help survive the acidity of the stomach
• Trophozoites (noninfective), exist inside the host and some times in fresh feces. They are highly motile amoebas, and reproduce by binary fission:
More common form of infection is the

- **Invasive amebiasis**: Symptoms occur 1-4 weeks after ingestion. These include nonspecific abdominal symptoms, such as watery, bloody and mucus containing diarrhea, abdominal pain, cramping, flatulence, weight loss, and chronic fatigue.

- **Invasive extraintestinal amebiasis**: Trophozoites carried via the bloodstream throughout the body.
  
  a) **Liver**: Liver abscess. Symptoms include: fever, abdominal pain, nausea, diarrhea, ulcers, constipation, gas, hepatomegaly, and weight loss.
  
  b) **Respiratory tract**: Symptoms include cough and chest pain
  
  c) **Brain**: This is very rare. Symptoms are headache, vomiting, and seizures.
The Course of Amoebiasis Due to *Entamoeba histolytica*

- **A**: Amoebas pass through the stomach as cysts.
- **B**: Amoebas emerge in the terminal small intestine.
- **C**: Amoebas form deep ulcers.
- **D**: Some amoebas pass into the bloodstream and infect other organs.
- **E**: Perforation of the large intestine leads to infection of the peritoneal cavity.
- **F**: Some amoebas form cysts and pass out of the body.
- **G**: Cysts remain alive in the environment and are transmitted in food and water.

Key:
- Red: Cyst
- Red and black: Trophozoite amoeba
- Pink: Trophozoite amoeba
- Light pink: Trophozoite amoeba
Cyst and Trophozoite of *Entamoeba histolytica* under the microscope

**Transmitton occurs in several ways:**

1) by ingesting cysts - contaminated food/drinks
2) by directly inoculating trophozoites in colon or other sites (ex. anal sex).
3) by fecal-oral self-inoculation (hand to mouth)
Acanthamoeba

- Primary amebic meningoencephalitis, Brain, spinal cord, eye infections in Swimming ponds and rivers, and lenses contaminant. free-living amebae
- Cyst and trophozoit enter through
  - Nasal membrane, pass to brain
  - Via wound
  - Penetration of the eye.
- Trophozoites migrate to the brain
- Entry of *Acanthamoeba* into the CNS occurs from skin ulcers or traumatic penetration, such as keratitis from puncture of the corneal surface.
- Contact lenses wearers who use tap water or contaminated saline to wash their contact lenses can become infected
  *Acanthamoeba* keratitis results from conjunctival inoculation
Naegleria fowleri

Enter via the nose when swimmers inhale contaminated water, passing directly into brain tissue, where they cause extensive hemorrhage and damage.

Early symptoms include headache, fever, lethargy, rhinitis, nausea, vomiting, and disorientation and resemble acute bacterial meningitis.

In most cases, patients die within a week.

The key to diagnosis is based on recent history of swimming in waters.
Flagellate

- *Trichomonas vaginalis* (genitourinary flagellates)
- *Giardia lamblia* (intestinal flagellates)
- *Trepanosoma* (hemoflagellates)
Trichomonas vaginalis (genitourinary flagellate)
- The organism Trichomonas vaginalis exists only as a trophozoite (no cyst stage)
- It has four free flagella that arise from a single stalk and a fifth flagellum, which forms an undulating membrane.
- T. vaginalis is STD, and most infections are asymptomatic or mild for both women and men.

In women, the infection is normally limited to the vulva, vagina, and cervix; it does not usually extend to the uterus. The mucosal surfaces may be tender, inflamed, eroded, and covered with a frothy yellow or cream-colored discharge, pruritus, and burning.

In men, the prostate, seminal vesicles, and urethra may be infected. About 10% of infected males have a thin, white urethral discharge. -The incubation period is from around 5 to 28 days.
Trichomonas vaginalis

- Basal body
- Nucleus
- Hydrogenosomes
- Axostyle
- Anterior flagella
- Trailing flagellum and undulating membrane
- Costa
- Parabasal body and Golgi apparatus
Transmission is by sexual intercourse, but contaminated towels, douche equipments, examination instruments, and other objects may be responsible for some infections. 

Infants may be infected during birth.
Blood and tissue protozoan infections

Hemoflagellates

- The hemoflagellates of humans include the genera:
- *Trypanosoma* (المثقبيات) and *Leishmania*

*There are two distinct types of human Trypanosomes:*

(1) African, which causes *Sleeping sickness*, and is transmitted by *tsetse flies*.

*Trypanosoma brucei rhodesiense and Trypanosoma brucei gambiense*

(2) American, which causes *Chagas disease* and is transmitted by *kissing bugs* (البق المقبل أو مصاص الدماء).

The causative parasite is *Trypanosoma cruzi*.

*The genus Leishmania,*

- Divided into a number of species infecting humans, causes

1. *Cutaneous* (Oriental sore)
2. *Mucocutaneous* (espundia)
3. *Visceral (kala-azar) leishmaniasis.*

- All of these infections are transmitted by *Sandflies*
African Trypanosoma: The genus Trypanosoma appears

1. In the blood as **Trypomastigotes** (it is a non-dividing form that is infectious) spread to lymph nodes, to the bloodstream, and, in terminal stages, to the CNS where they produce the typical sleeping sickness syndrome. In addition, inability to eat, unconsciousness, and death.

2. **Amastigote** is the intracellular dividing form in the cytoplasm of vertebrate cells.

3. **Epimastigote** is found in the intestinal tract of the insect vector.
   - CNS involvement is most characteristic of African Trypanosomiasis.
   - Trypanosoma brucei gambiense infection is chronic and leads to progressive diffuse meningoencephalitis, with death after in 1–2 years.

- The Trypanosomes are transmissible through the placenta, and congenital infections occur in hyperendemic areas.
American Trypanosoma:
Trypanosoma cruzi has three developmental stages:
1. **Epimastigotes** in the vector
2. **Trypomastigotes** (in the bloodstream),
3. **Amastigote** (rounded intracellular stage).

Infective forms of *T. cruzi* (Trypomastigotes) *are introduced when infected bug feces* are rubbed into the conjunctiva, the bite site, or a break in the skin.

At the site of *T. cruzi* entry, *there may be a subcutaneous inflammatory nodule or Chagoma*. Swelling of the eyelids, especially in children. The primary lesion is accompanied by fever, acute regional lymphadenitis, and dissemination to blood and tissues.

**Interstitial myocarditis is the most common serious condition in chagas disease.** Other organs affected are the liver, spleen, and bone marrow.
T. cruzi causes cutaneous stage (chagoma)
**Giardia lamblia (intestinal flagellate)**

- Also referred to as **Giardia duodenalis or Giardia intestinalis**
- Is the causative agent of Giardiasis and is the **only common pathogenic protozoan found in the duodenum and jejunum of humans.**

**Giardia exists in two forms:**

1. The trophozoite
2. The cyst forms.

- After adhering to the intestinal villi, the parasites pass into the colon, they typically **Encyst**, and the cysts are passed in the stool (they are ellipsoid, thick-walled, highly resistant, contain 2-4 nuclei).
- Large numbers of parasites attached to the bowel wall may cause irritation and inflammation of the duodenal or jejunal mucosa. **Stools may be watery, semisolid, greasy, and foul smelling at various times during the course of the infection.**
- Symptoms of **malaise, weakness, weight loss, abdominal cramps, distention, and flatulence** may continue for long periods.
Contamination of water, food, or hands/fomites with infective cysts.

Trophozoites are also passed in stool but they do not survive in the environment.

1 = Infective Stage
2 = Diagnostic Stage

Cyst

Cyst → Trophozoites → Cyst
• **Balantidium coli** is the only ciliate known to cause disease in humans

• Commonly found in animal intestinal tracts

• Humans become infected by consuming food or water contaminated with feces containing cysts

• Trophozoites attach to the mucosal epithelium lining the intestine

• *B. coli* infections are generally asymptomatic in healthy adults

• Balantidiasis occurs in those with poor health
  – Characterized by persistent diarrhea, abdominal pain, and weight loss
Plasmodium-Malaria (swamp fever)

Four species of *plasmodium* cause malaria in humans:

1. *Plasmodium vivax*
2. *P. falciparum*
3. *P. malariae*
4. *P. ovale*

- The two most common species are *P. vivax* and *P. falciparum*, with *P. falciparum* being the most pathogenic of all.
- Transmission to humans is by the bloodsucking bite of *Female Anopheles* mosquitoes.
- Human infection results from the bite of an infected mosquito, through which the *Sporozoites* are injected into the bloodstream.
- The *Sporozoites* rapidly enter parenchymal cells of the liver, where the first stage of development in humans takes place.
- Subsequently, numerous *Merozoites*, rupture and leave the liver cells, enter the bloodstream, and invade erythrocytes (RBC).
- The merozoites do not return from red blood cells to liver cells.
- During the erythrocytic cycles, Merozoites become differentiated as male or female gametocytes. The gametocytes must be taken up and ingested by bloodsucking female anopheles.

- *Plasmodium vivax* and *p. ovale* may persist as dormant forms, or Hypnozoites, after the parasites have disappeared from the peripheral blood. (Relapse) occurs when Merozoites from hypnozoites in the liver break out, and succeed in reestablishing a RBC infection.
Gametocytes fuse and sporozoites develop

Mosquito

Skin

Sporozoites

Capillary

Lymph vessel

Lymph node

Liver cell entry

Liver

Liver cell rupture, merozoite release

RBC penetration

Development into gametocytes

Asexual reproduction

Uptake during blood meal
Helminthic Parasite

- Most infections are acquired by ingestion of the egg or larval stage, with the exception of the hookworms, human threadworms, and schistosomes, whose larvae penetrate the skin, and the filarids, which are vector-borne.

- **Eosinophilia** is a cardinal feature of a tissue infection by parasitic worms.

- Most helminths do not multiply by asexual multiplication in the human host: one egg or one larva yields one worm. The exception is *Echinococcus granulosus, which multiplies asexually within hydatid cysts.*
Nematodes- Roundworms

• Intestinal roundworms:
  – *Enterobius* (Pinworm)
  – *Ascaris* (Giant intestinal roundworm)
  – *Necator / Ancylostoma* (Hookworm)

• Tissue roundworms
  – *Trichinella spiralis* (is the smallest known nematode parasite of humans)
Enterobius vermicularis
الدودة الشعرية او الديوسية
(PINWORM—INTESTINAL NEMATODE)
- The organism female pinworms have a slender, pointed posterior end. males are approximately have a curved posterior end.
- Pinworms infect mostly children.
- The main symptom associated with pinworm infections is perianal pruritus, especially at night, caused by a hypersensitivity reaction to the eggs that are laid around the perianal region by female worms, which migrate down from the colon at night.
- Scratching the anal region promotes transmission, as the eggs are highly infectious within hours of being laid (hand-to-mouth transmission).
- Irritability and fatigue from loss of sleep occur.
- Eggs are recovered using the “scotch tape” technique in the morning before a bowel movement.
- Infectious larvae are often visible inside the egg.
- Because the eggs are light weight and highly infectious, it is important for bed linens, towels, and clothing to be washed in hot water to prevent re-infection.
Life Cycle

1. Eggs on perianal folds, Larvae inside the eggs mature within 4 to 6 hours.

2. Embryonated eggs ingested by human

3. Larvae hatch in small intestine

4. Adults in lumen of cecum

5. Gravid ♀ migrates to perianal region at night to lay eggs

<i> = Infective Stage

<a> = Diagnostic Stage
Diagnosing Pinworm Disease

A. Clear plastic tape is pulled back over the end of the slide to expose the gummed surface.

B. The tape, still attached to the slide, is looped over a wooden stick.

C. The gummed surface of the tape is touched several times to the anal region.

D. The tape is replaced on the slide.

E. The slide is smoothed down with cotton or gauze. It is then examined under a microscope for pinworm eggs.

D- shape egg
**Trichuris trichiura** (whipworm — intestinal nematode)

الدودة السوطية

- The anterior end of the worms is slender, and the posterior end is thicker, giving it a “buggy whip” appearance, hence the name whipworm.

- Adult whipworms inhabit the colon, where male and female worms mate.

  - Females release eggs that are passed in the feces, and eggs become infective after about 3 weeks of incubation in moist and shady soil.

  - Humans acquire the infection by eating foods contaminated with infective eggs.

- Once eggs are swallowed, the larvae hatch in the small intestine, where they mature and migrate to the colon.
- The anterior ends of the worms lodge within the mucosa of the intestine, leading to small hemorrhages with mucosal cell destruction and infiltration of eosinophils, lymphs, and plasma cells.
- Other symptoms: lower abdominal pain, distention, and diarrhea.
- Severe infection may lead to profuse bloody diarrhea, cramps, urgency, and rectal prolapse.
- Occasionally worms migrate to the appendix, causing appendicitis.
Egg is Barrel-shaped/lemon with hyaline polar plug at each end
Ascaris lumbricoides
Intestinal Nematodes

- Adult Ascaris are large: females are 20–50 cm long, and males are 15–30 cm long
  - humans acquire the infection after eggs are ingested; larvae hatch in the duodenum, penetrate through the mucosa, migrate in the circulatory system, lodge in lung capillaries, penetrate the alveoli, and migrate from the bronchioles to the trachea and pharynx

- Larvae are swallowed and return to the intestine and mature into adults. after mating, females can release 200,000 eggs per day, which are passed in the feces and are infective after about 1 month in the soil
  - adult worms may cause mechanical obstruction of the bowel and bile and pancreatic ducts. Bowel perforation and peritonitis occur, vomiting, and abdominal pain.
- Larvae migrating through lungs induce an inflammatory response (pneumonitis), leading to bronchial spasm, mucus production, and löffler syndrome (cough, eosinophilia, and pulmonary infiltrates).
Life cycle of *Ascaris* spp.

1. Infective eggs are swallowed
2. Eggs reach small intestine and hatch
3. L3 larvae migrate to hepatic portal through intestinal wall (1-2 dpi)
4. Larvae enter lungs (5-6 dpi) and alveolar spaces causing cough
5. Coughed-up larvae are swallowed
6. Larvae reach small intestine for a second time, mature (50-55 dpi) and adult worms lay eggs
7. Eggs are passed in feces and embryonate becoming infective in a few weeks

dpi - days post-infection
Egg have thick shell and protein coat
**Trichinella spiralis** is acquired by eating raw or improperly cooked pork infected with the larval stage of these nematodes. In the small intestine, the larvae molt into adult worms, and, after mating with male worms, the female worms release live larvae. The larvae penetrate the intestine, circulate in the blood, and eventually encyst in muscle tissue.

- After the first week, the infection may cause diarrhea, abdominal pain, and nausea. Intestinal symptoms are mild to none and often go unnoticed.

The main symptoms of trichinellosis are primarily caused by the larvae encysted in muscle tissue, high fever, cough, and eosinophilia. As larvae encyst, edema occurs, highly active muscle tissue such as the diaphragm, tongue, and extraocular muscles are commonly infected.
Trichinella spiralis

(a) Infested meat is ingested

(b) Larvae deposited by adult worms into blood or lymph vessels

(c) Larvae lodge in muscle and encyst

150 μm
Platyhelminthes - Flatworms

- **Trematodes** – Flukes - nonsegmented
  - *Schistosoma* - blood fluke

- **Cestodes** – Tapeworms - segmented
  - *Taenia* – beef or pork tapeworm
- The adult worms are long and can live within the venous system:
  - **S. mansoni**: inferior mesenteric veins of large intestine (intestinal schistomiasis)
  - **S. japonicum**: inferior and superior mesenteric veins of small intestine
  - **S. haematobium**: veins of urinary bladder (urinary schistomiasis).
- Egg with feces or urine, produce larvae **Meracidium** that developed in water snails into **Cercariae**.
- Humans acquire the infection when they contact water contaminated with the infectious **Cercariae**. Cercariae penetrate skin lipids and begin to burrow into exposed skin.
- The cercariae have penetrated the epidermis and transformed into **Schistosomules**, which enter the peripheral circulation, where they eventually become **adults in the hepatoporal system or the bladder**.
- The female Schistosomes begin releasing eggs approximately 5–8 weeks after infection.
The most significant pathology is associated with the schistosome eggs, not the adult worms.

- Female Schistosomes can lay hundreds or thousands of eggs per day within the venous system.
- When eggs are released, many are swept back into the circulation and lodge in the liver or urinary bladder, while other eggs are able to reach the lumen of the intestine and pass out with the feces or urine.

Agranulomatous reaction surrounds the eggs and leads to fibrosis of the liver. In chronic cases, portal hypertension, accumulation of ascites in the abdominal cavity, hepatosplenomegaly, and esophageal varices, urinary tract involvement: urethral pain, increased urinary frequency, dysuria, hematuria, and bladder obstruction leading to secondary bacterial infections.
Schistosoma – blood fluke

(b) Life cycle of Schistosoma, cause of schistosomiasis.
Cestodes - Tapeworms

• Tapeworm parts:
  • **Scolex**
    head with attachment site
  • **Proglottids**
    body segments with testes and ovaries
*Taenia saginata* (beef tapeworm) and *Taenia solium* (pork tapeworm)
- If humans eat “beef” or “pork” containing the larvae called *cysticerci*, they acquire infections of *T. saginata* and *T. solium*, respectively.
- The *cysticerci*, develop into adult worms that can reach lengths of several meters in the intestine.
- Adult worms generally cause few problems, and most are asymptomatic; mild intestinal symptoms include diarrhea and abdominal pain.
- In the intestine, egg-filled segments break off from the adult worm and pass out with human feces.
- when the eggs from human feces are consumed by cows (*T. saginata*) or pigs (*T. solium*), *larvae hatch from the eggs, migrate, and encyst* as *cysticerci* in various tissues, including cow muscle (beef) or pig muscle (pork).
- humans become infected when they eat raw or undercooked meats containing the *cysticerci*.
- These *cysticerci* then develop into adult worms in the human intestine.
THE LIFE CYCLE OF *TAENIA* SPP.  
(THE PORK AND BEEF TAPEWORMS OF HUMANS)

Eggs (or proglottids containing eggs) are passed in the host's feces

Eggs are ingested by an appropriate intermediate host: pigs for the pork tapeworm, cattle for the beef tapeworm

Cysticercus grows into an adult, sexually reproducing tapeworm in the small intestine.

Humans are infected when they ingest a cysticercus in raw or undercooked pork or beef products

The egg hatches in the small intestine, and the larva within migrates to the muscles and grows into a cysticercus

Humans can be infected with cysticerci of *Taenia solium* = cysticercosis

(Parasites and Parasitological Resources)
Scolex of *T. solium*  Scolex of *T. saginiata*

Scolex of *T. saginiata* has 4 suckers and no hook. *T. solium* has 4 suckers in addition to a double row of hooks.
Arthropods as Vectors

– Phylum: Arthropoda (exoskeleton, jointed legs)
  • Class: Insecta (6 legs)
    – Lice, fleas, mosquitoes
  • Class: Arachnida (8 legs)
    – Mites and ticks
    – May transmit diseases (vectors)

Figure 12.31, 32
Arthropods as Vectors

(a) Human louse

(b) Rat flea

(c) Deer fly

(d) Kissing bug

Figure 12.33