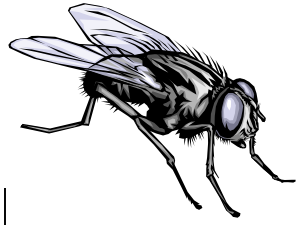


An Introduction to Forensic Entomology Part I

Dead do tell tales……

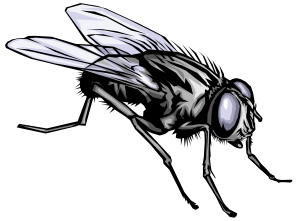
Prof. Abdelwahab A. Ibrahim

Forensic Entomology

- Definition: The use of the insects, and their arthropod relatives that inhabit decomposing remains to aid legal investigations.
- Forensic Entomology has 3 Broad Categories:
  - Medico-legal - criminal component of the legal system and deals with the necrophagous (or carrion) feeding insects that typically infest human remains.
  - Urban - both criminal and civil components as urban pests may feed on both the living and the dead.
  - Stored Products – Civil & criminal cases involving food contamination

Medicolegal Forensic Entomology

- Often focuses on violent crimes
  - Establishing timelines (time since death to time of discovery (postmortem interval or PMI)
  - site of human death based on identification of arthropods collected from or near corpses.
  - Movement of the corpse, manner and cause of death.
  - Cases involving possible sudden death
  - Traffic accidents with no immediately obvious cause
  - Possible criminal misuse of insects
    - Association of suspects with the death scene
    - Detection of toxins or drugs → insect larvae



History……

History

- The idea of using insect activity as a means to catch criminals is not new.
- First reference to forensic entomology (around the year 1300), a Chinese mandarin named Sung T'zu made the first recorded observations of the usefulness of insects in solving crimes.
- Sung wrote in one of the earliest criminology works, entitled *Washing Away of Wrongs*, that "during the hot months, if maggots have not yet appeared at the nine orifices [of the body], but they have appeared at the temples, hairline, rib cage, or belly, then these parts have been injured."
- In the western world Forensic Entomology was not born until 1855 when Dr Bergeret d'Arbois used entomological knowledge to help the police in Paris solve the murder of a child.

Brief History

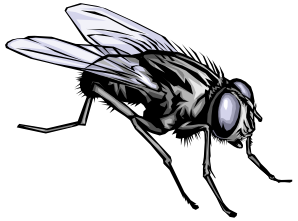
- Sung T'zu (1235)
  - First reference to forensic entomology
- Bergeret (1855)
  - Use forensic entomology to solve a case of a long-dead infant
- J.P. Megnin (1894)
  - "La Faun des Cadavres: Application l'entomologie a la Medicine Legale"
- Hall 1948
  - Monograph on identification of blowflies
- Pekka Nuorteva of Finland (1970's)
  - Rekindled interest in the technique, published series of case histories
- Keh (1985), Smith (1986), Catts and Goff (1992)
  - Textbooks and reviews

What do Forensic Entomologists Do?

- Forensic Entomologists apply their knowledge of entomology to provide information for criminal investigations.
- A forensic entomologist's job may include:
  - Identification of insects at various stages of their life cycle, such as eggs, larva, and adults.
  - Collection and preservation of insects as evidence.
  - Determining an estimate for the postmortem interval or PMI (the time between death and the discovery of the body) using factors such as insect evidence, weather conditions, location and condition of the body, etc.
  - Testifying in court to explain insect-related evidence found at a crime scene.

Succession

- A cadaver is a very rich but ephemeral (short-lived) resource
- There is tremendous competition among organisms, especially in the early stages of decomposition.
- Insect colonization of a corpse occurs in a series of stages.
  - Different groups are adapted to different decompositional stages of a corpse.
  - Thus, there is a fairly predictable sequence of colonization



Stages of decomposition……

Five Stages of Decomposition Fueled by Insect Activity.

- Fresh
- Bloat
- Decay
- Post-decay
- Dry (skeletal)

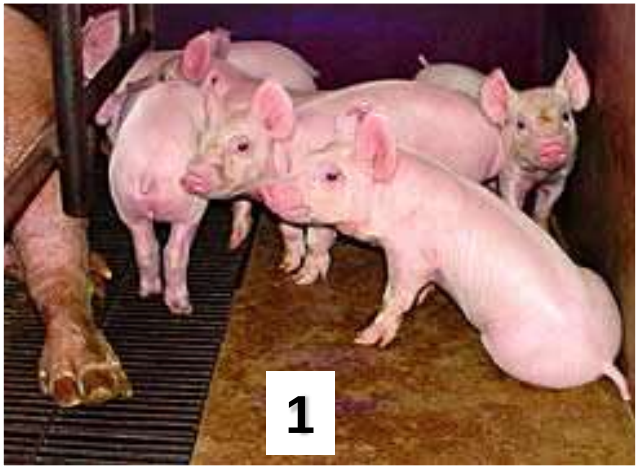
Stages of Decomposition

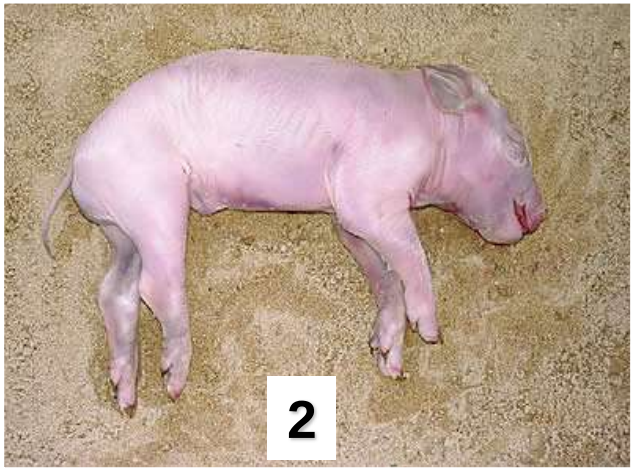
- A. Fresh Stage (Days 1-2)
  - Commences at death, ends when bloating is first evident. Breakdown of protein and carbohydrates into simpler compounds
- B. Bloated Stage (Day 2-6)
  - Putrefaction begins. Gasses produced by anaerobic bacteria inflate the abdomen.
- C. Decay Stage (Days 5-11)
  - Abdominal wall breaks allowing gasses to escape. Carcass deflates.
- D. Post-decay Stage (Days 10-25)
  - In dry habitats, remains are skin, cartilage, and bones. In wet habitats, wet, viscous material in the soil under the remains.
- E. Dry Stage (Days 25+)
  - Mainly bones and hair remain. Odor is primarily that of normal soil and litter. Can last several months to years.

Succession

Fresh

Bloated

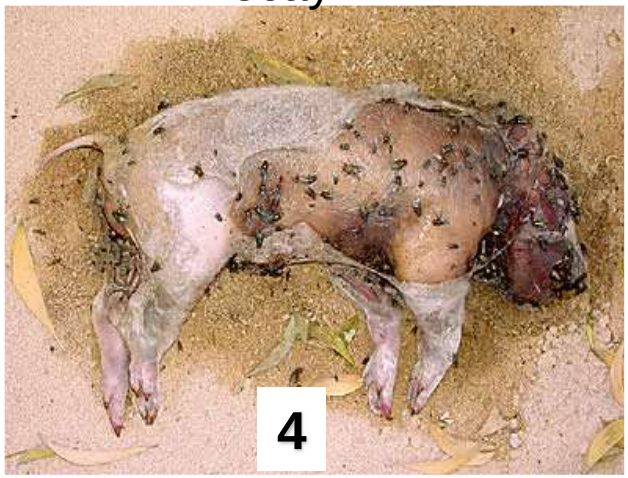


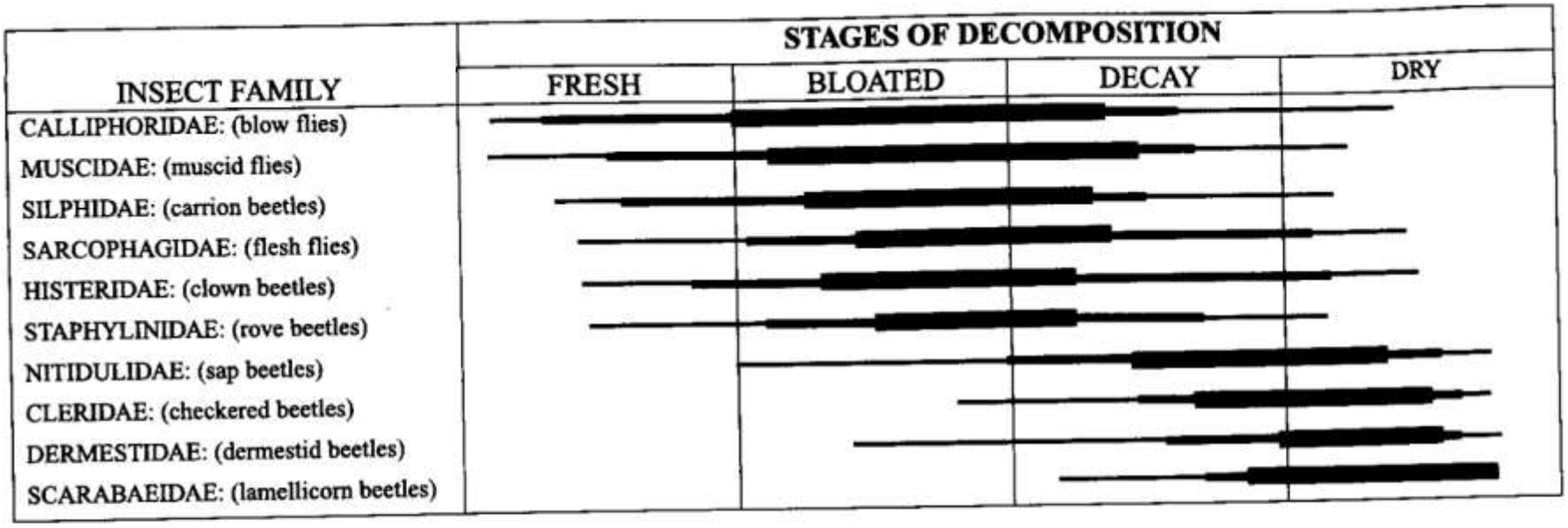


Decay

Post-Decay

Dry

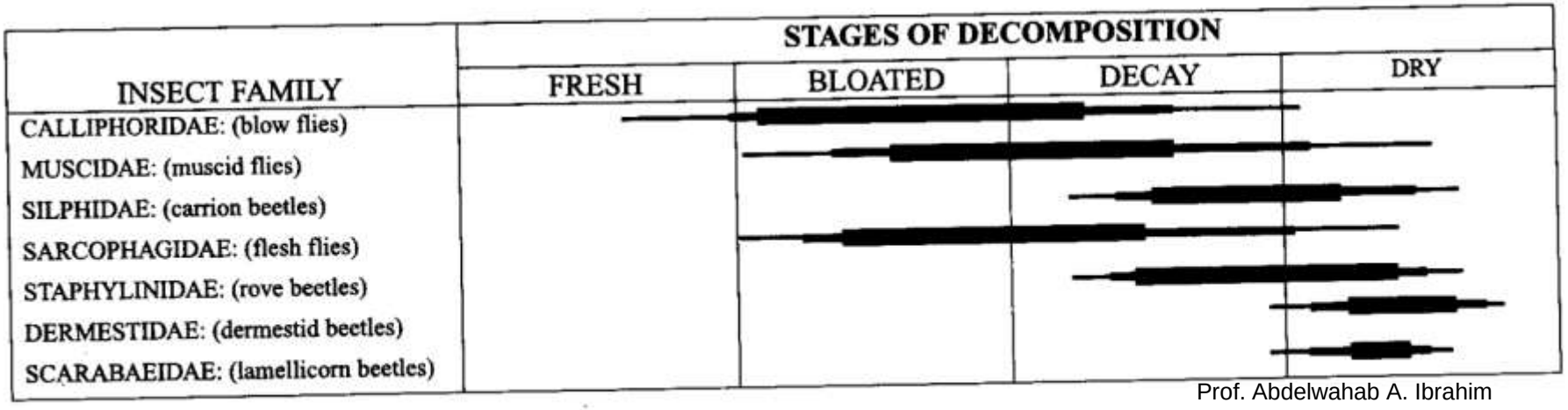




*Each stage of decomposition is given the same amount of space in this table.

Indicates a small number of individuals present.
Indicates a moderate number of individuals present.
Indicates a large number of individuals present.

(a)



*Each stage of decomposition is given the same amount of space in this table.

Major Groups of Insects Associated with Cadavers

- Flies
  - Blowflies
  - Flesh Flies
  - House Flies
  - Cheese Skippers

- Beetles
  - Carrion Beetles
  - Dermestids
  - Scarab Beetles

Blue Bottle Flies (Blow flies)
Family name: Calliphoridae

- Blowflies often are an attractive blue-green, metallic color, leading to the common English names, blue-bottles and green-bottles.

- They also come in a non-metallic, brown form, but all blowflies usually relatively large flies.

Green Bottle Flies (Blow flies)
Family name: Calliphoridae

Blowflies can pick up faint traces of the odor of decay from up to 20 km away and lay their eggs in a suitable corpse.

Blow flies are one of the first insects to arrive at a cadaver – they prefer fresh, moist flesh.

Flesh Flies
Family name: Sarcophagidae

Most flesh flies breed in dead animals, dung, or decaying material, but a few species lay their eggs or larvae in the open wounds of mammals; hence their common name.

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Common House Flies
Family name: Muscidae

- Adults are most common at corpses in the early stages of decomposition when the corpse is moist.

- The larvae are usually dung feeders.

Cheese Skipper
Family name: Piophilidae

Cheese Skippers have been found in coffins buried up to 3 m deep and in corpses up to 10 years old.

Cheese flies are attracted to the cheesy odor which emanates from a corpse during the later stages of decomposition, particularly when the body is undergoing butyric fermentation. They are also common pests of cheeses and hams.

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Carrion Beetles

- The first beetles arrive at a corpse soon after the body begins to putrefy.
- Flies, on the other hand, prefer fresher meat.
- In contrast to the flies, beetles have chewing mouthparts and can manage tougher foods than the semi-liquid material that fly larvae are so efficient at exploiting.
- Several beetle types make their living out of corpses.
- The early arrivals tend to be predatory adults that feed on fly larvae.
- Some of these species lay their eggs in the corpse, and the emerging larvae, which share their parents' powerful jaws, also feed on fly larvae.

Carrion Beetles
Family name: Silphildae

There are over 200 species in this family, but the ones that eat dead flesh are those that belong to the subfamily Nicrophorinae

More about the Silphid Famiily

- Silphids are large carrion beetles that feed on both carrion and fly larvae.

- Even though adults have been recorded feeding on carrion, they cannot survive on it alone, and die if they do not have access to maggots.

Hister (clown) beetles
Family name: Histeridae

- They are among the first beetles to arrive at carrion.
- They generally hide under a corpse during the daylight, and only become active at night when they enter the maggot-infested part of the corpse to capture and devour maggots.
- The adults feed on both the larvae and pupae of all species of blowfly.
- The adults lay their eggs in the corpse, and the larvae feed on blowfly pupae when they emerge.

Sap Beetles
Family name: Nitidulidae

- Nitidulids (sap beetles) are small to minute terrestrial beetles.

- They feed on tree sap, fungi, fruit juices, carrion, flowers or leaves.

Rove Beetles
Family name: Staphylinidae

- They eat the fauna residing on and in a corpse
- Adults are early visitors to a corpse and they feed on larvae and eggs of all species of fly, including predatory fly larvae.
- They lay their eggs in the corpse, and the emerging larvae are also predators.

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Hide Beetles
Family name: Dermistidae

- Late-arriving species tend to be specialist scavengers which feed on tougher parts like skin and tendons as the body dries out.
- The dominant late stage scavengers include the larvae of hide beetles (Dermestidae).

Ham beetles (Checkered Beetles) Family name: Cleridae

- Clerids are elongate beetles that often have a metallic sheen or are colored red or yellow.
- Both the larvae and the adults are predatory, feeding on other insects.
- The Ham beetle is common in the later stages of decomposition of a carcass.
- The larvae feed on dried fat and pupate inside the empty pupal cases of flies, after sealing the opening with silk.

Scarab Beetles
Family Scarabaeidae

Like the dermestids, scarab beetles arrive when the body is completely dry

Carcass beetles
Family name: Trogidae

- Carcass beetles are large beetles with very thick exoskeletons and uniform dark coloration.
- They are among the last beetles to inhabit a carcass.
- They feed on dried remains such as skin and ligaments.
- Both adults and larvae feed on the carcass and the larvae live in vertical burrows underneath it when they are not foraging.

Examples of Coleoptera (Beetles)

Early Stage Decomposition

Carrion Beetles (*Silphidae*)
Adults & larvae feed on fly larvae

Early to Late Stage Decomposition

Rove Beetles
(*Staphylinidae*)
Predator of fly eggs

Clown Beetles
(*Histeridae*)
Predator of fly eggs

Late Stage Decomposition

Ham & Checkered Beetles
(*Cleridae*)
Predator of flies & beetles;
also feed on dead tissue

Skin Beetles (*Dermestidae*)
Feed on dried skin & tissues

Hide Beetles
(*Scarabidae*)
Usually the last to arrive

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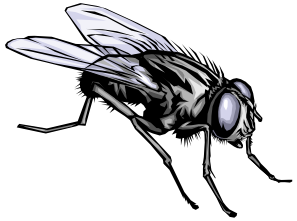
Informational Source: http://naturalsciences.org/files/documents/csi_tg_overview.doc
Images: http://www.cals.ncsu.edu/course/ent425/library/spotid/coleoptera/coleoptera.html & http://www.forensicflies.com/beetles.htm



Life cycles of forensic insects……

After Death

- As the body decays, odors attract insects to the dead body. Levels of putricine (decomp. enzyme,) sulfur and methane compounds send up an "open for dinner" flare.
- The flies (order Diptera) are the first to arrive. Blowflies (F. Calliphoridae) and flesh flies (F. Sarcophagidae) are flesh feeders and will be the first in line.
- Flies can arrive within minutes or up to a couple hours after death.
- In many cases flies arrive before the completion of a crime and are a silent witnesses.

The Story Maggots Tell

- Blowfly maggots are of two forms: smooth maggots, and 'hairy' maggots.
- The smooth maggots belong to pioneer flies that are purely corpse feeders.
- 'Hairy' maggots will often feed on corpses, but they are also active predators that feed on smooth maggots.
- Because they are predators, the arrival of the secondary flies that produce hairy maggots is normally later than that of the pioneer maggots.
- Beetle maggots also tend to be predatory like the adult beetles.

Fly Life Cycle

- If no trauma is present on the body, female blowflies will lay eggs in exposed body openings (ears, nose, mouth, anus, genitalia.)
- Flesh flies don't lay eggs, they deposit larvae.
- The colonization pattern is due to the mouth parts of adult flies.
  - Blowflies and flesh flies have spongy mouth parts. They lack piercing apparatus that can cut through unbroken human skin. The body openings provide a moist, warm environment for larvae development.

Blowflies

<u>Blowfly Classification</u>
Kingdom: Animalia
Phylum: Arthropoda
Subphylum: Uniramia
Class: Insecta
Order: Diptera
Family: Calliphoridae

Blowfly Eggs

- Small, 2-3 mm length, elongate, whitish to yellowish
- Found in large clusters in and around body openings as well as injuries
- Clearly visible to naked eye
- Colder months may see fewer in numbers
- Can be found in more hidden locations such as under eyelids or in nostrils
- Eggs typically hatch within hours but may take up to 2-3 days depending on conditions

Blowfly Larvae

- One fairly small and featureless larvae hatches from each egg
- The body tapers from anterior to posterior – Mouth at the anterior, spiracles at the posterior
- Posterior contains breathing apparatus called spiracles
  - Spiracles, along with body size and shape provide important info for identification

Blowfly larvae

- Large numbers of blowfly typically hatch at a time and remain together while they feed on a corpse
- These maggot masses generally form in the head region and move down the torso as they feed.
- As they feed the larvae secrete digestive enzymes which allows them to consume nearly all the soft tissue on the corpse

Blowfly life cycle

- Blowfly larvae go through three instars (molts)
- They are considered fully grown at the third instar
- This can occur in several days or several weeks depending on species, environmental conditions and number of larvae present

Pupa Stage

- After the 3rd instar larvae go through a drastic behavioral change
  - they crawl away from the corpse and burrow down into the soil to transform into the pupal stage and complete the life cycle

Pupa

- The pupa form when the outer larval skin hardens and shrinks
- Inside this "case" the adult blowfly will form
- Once the adult fly emerges, the pupal case does not decompose. It can remain under a corpse for hundreds of years
- Pupal cases can provide valuable forensic info to investigators long after a crime has been committed.

The blow fly life cycle has six parts: the egg, three larval stages, the pupa, and adult.

130 hours

143 hours

23 hours

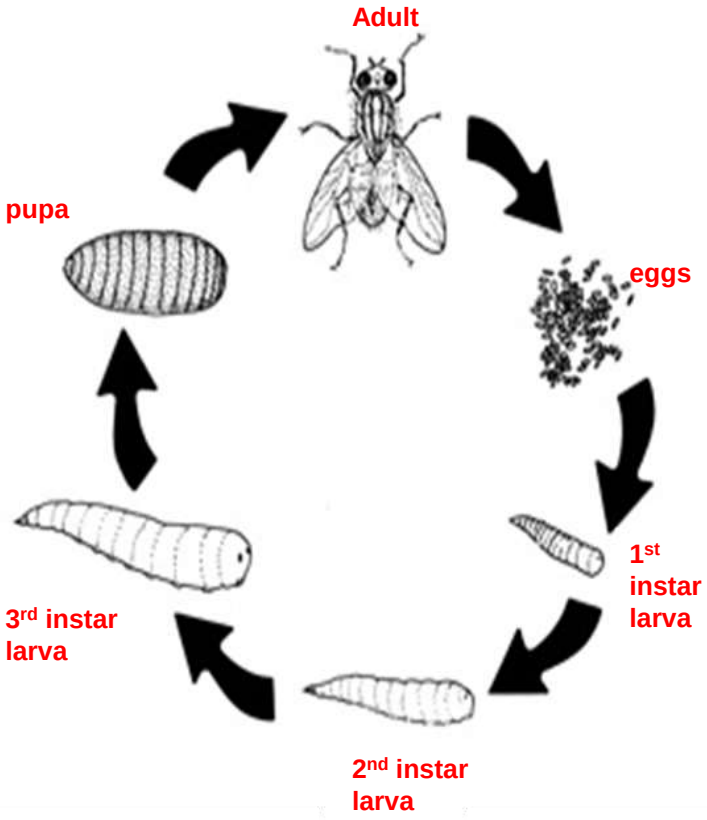
27 hours

22 hours

At 70 degrees F, each stage in a blow fly's life takes a known amount of time to complete...

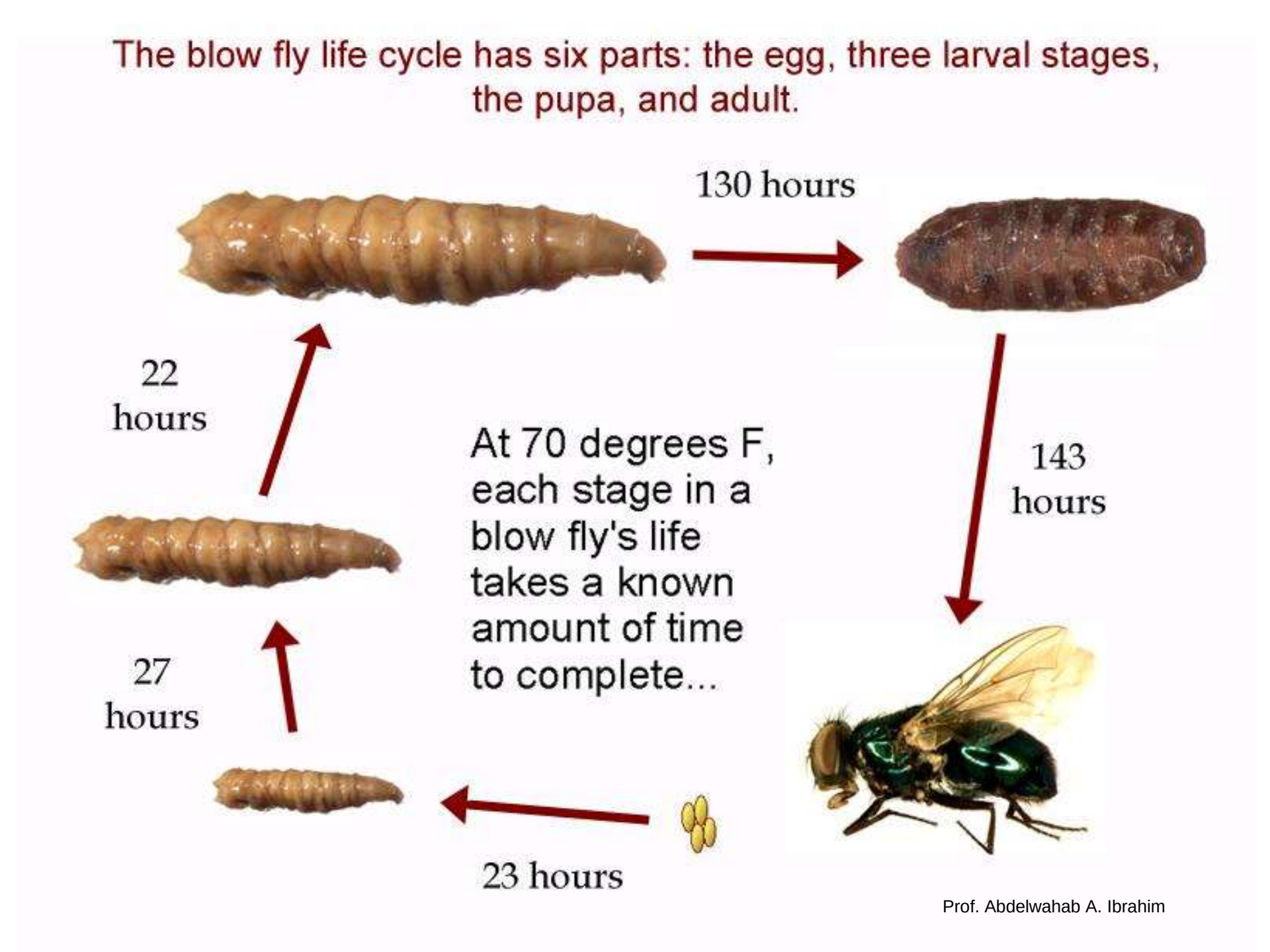
Blow Fly Metamorphosis

- 1st – Adult flies lay eggs on the carcass especially at wound areas or around the openings in the body such as the nose, eyes, ears, anus, etc.
- 2nd – Eggs hatch into larva (maggots) in 12-24 hours.
- 3rd– Larvae continue to grow and molt (shed their exoskeletons) as they pass through the various instar stages.
  - 1st Instar - 5 mm long after 1.8 days
  - 2nd Instar - 10 mm long after 2.5 days
  - 3rd Instar – 14-16 mm long after 4-5 days
- 4th – The larvae (17 mm) develop into pupa after burrowing in surrounding soil.
- 5th – Adult flies emerge from pupa cases after 6-8 days.



It takes approximately 14-16 days from egg to adult depending on the temperatures and humidity levels at the location of the body.

The blow fly life cycle has six parts: the egg, three larval stages, the pupa, and adult.



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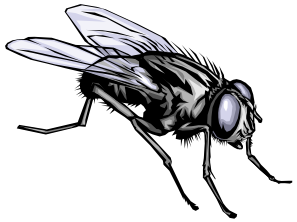
General Life cycle of Beetles

- A single female may lay from several dozen to several thousand eggs during her lifetime.
- Eggs can be laid singly or in clumps
- Larva feed voraciously – they can be predatory.
- The larval period varies between species but can be as long as several months.
- In many species the larvae simply increase in size with each successive instar as more food is consumed. In some cases, however, more dramatic changes occur.
- beetle larvae pupate, and from this pupa emerges a fully formed, sexually mature adult beetle, or imago.
- Adults have an extremely variable lifespan, from weeks to years, depending on the species.



Factors affecting Decomposition,

Life cycles of forensic insects and PMI

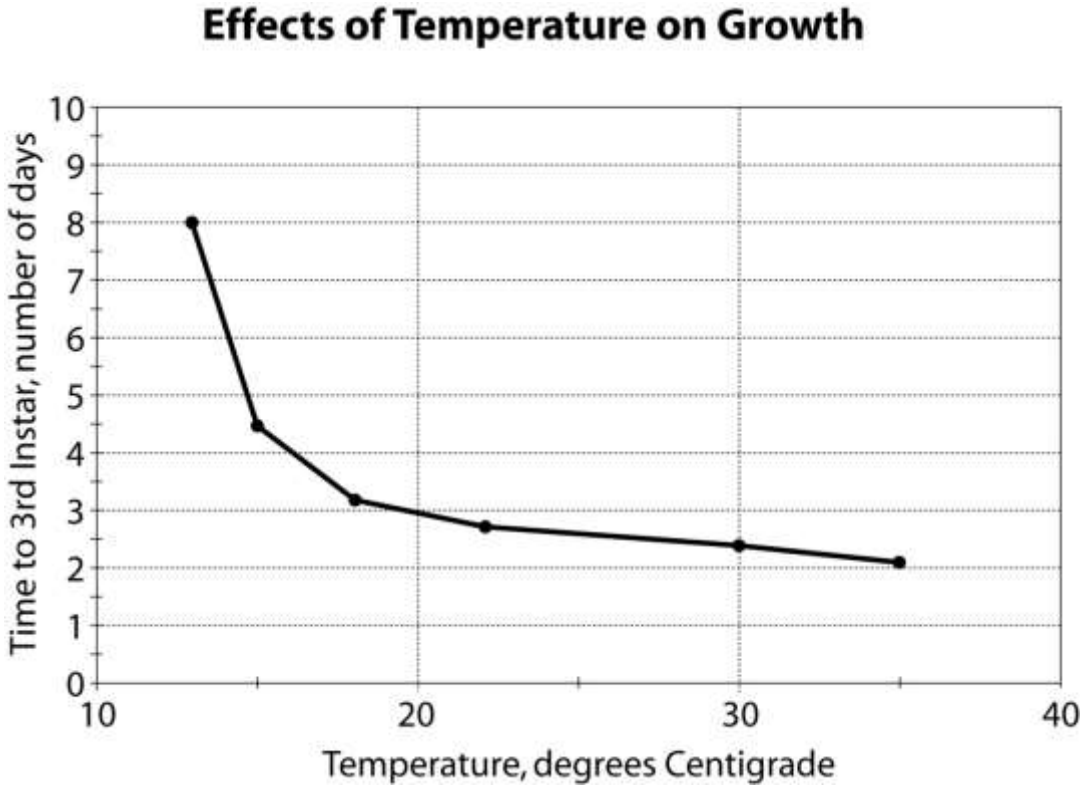
Factors Affecting Decomposition and insects

- Temperature/humidity
  - Lower temps slow down microbes & insects
  - Low humidity dries corpse, mummifies
- Access
  - Submerged vs. on land
  - In open vs. interred vs. in shade
- Reduction & Cause of Death
  - Large wounds lead to faster decomposition
  - Scavangers/vertebrate predators important too
- Coverings & Pesticides
  - Tightly wrapped bodies decompose slower
  - Heavy clothing slows decomposition more than thinner clothing
- Percent of body fat in corpse
  - More fat (higher water content, better heat retention) means faster decomposition
- Drugs & chemicals
  - Insects on coke or meth burn through a body faster, bodies with arsenic decompose slower.

Factors Affecting Decomposition

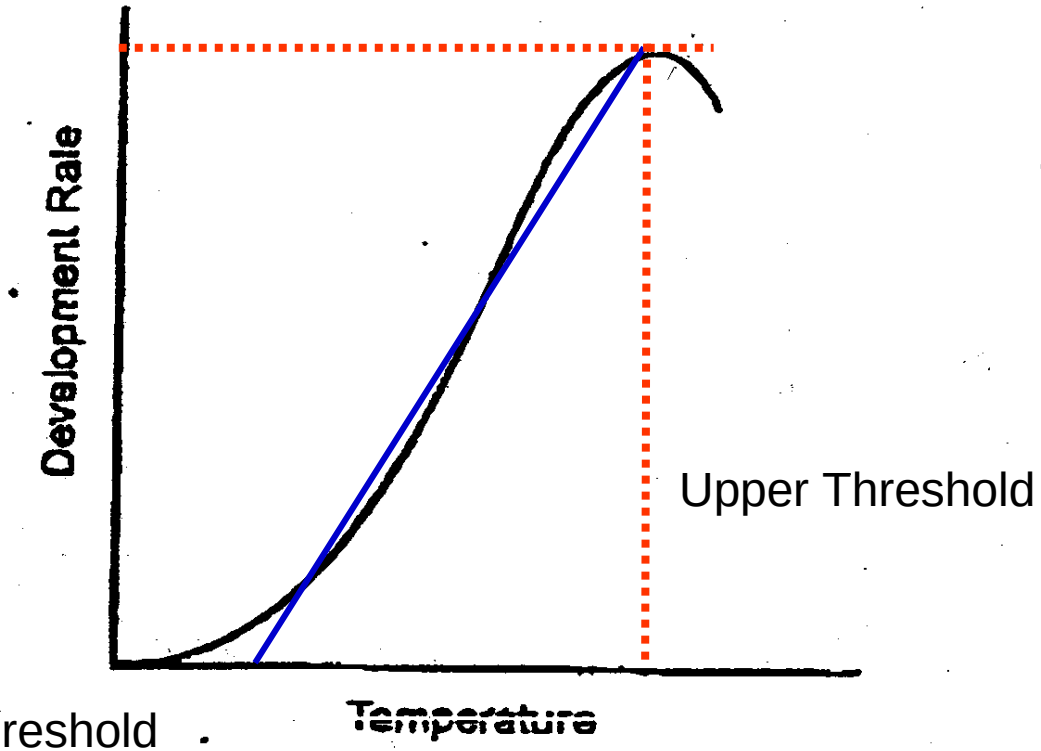
Temperature:

- The higher the temperature (within limits), the faster the growth.

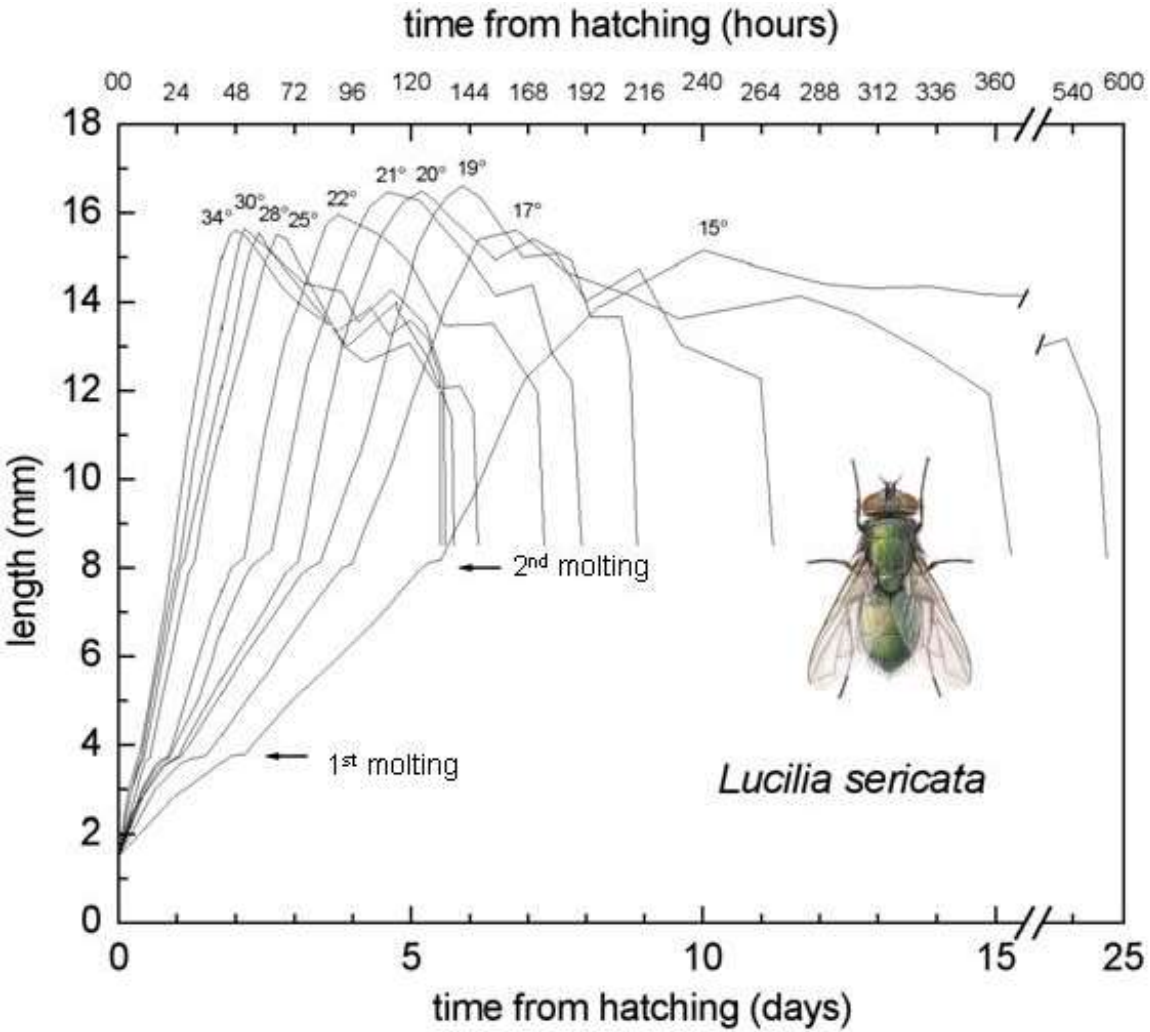


Temperature Effects on Insect Growth

- **How do we measure insect growth?**
- **Linear approach**



Temperature-Dependent Development of Flies



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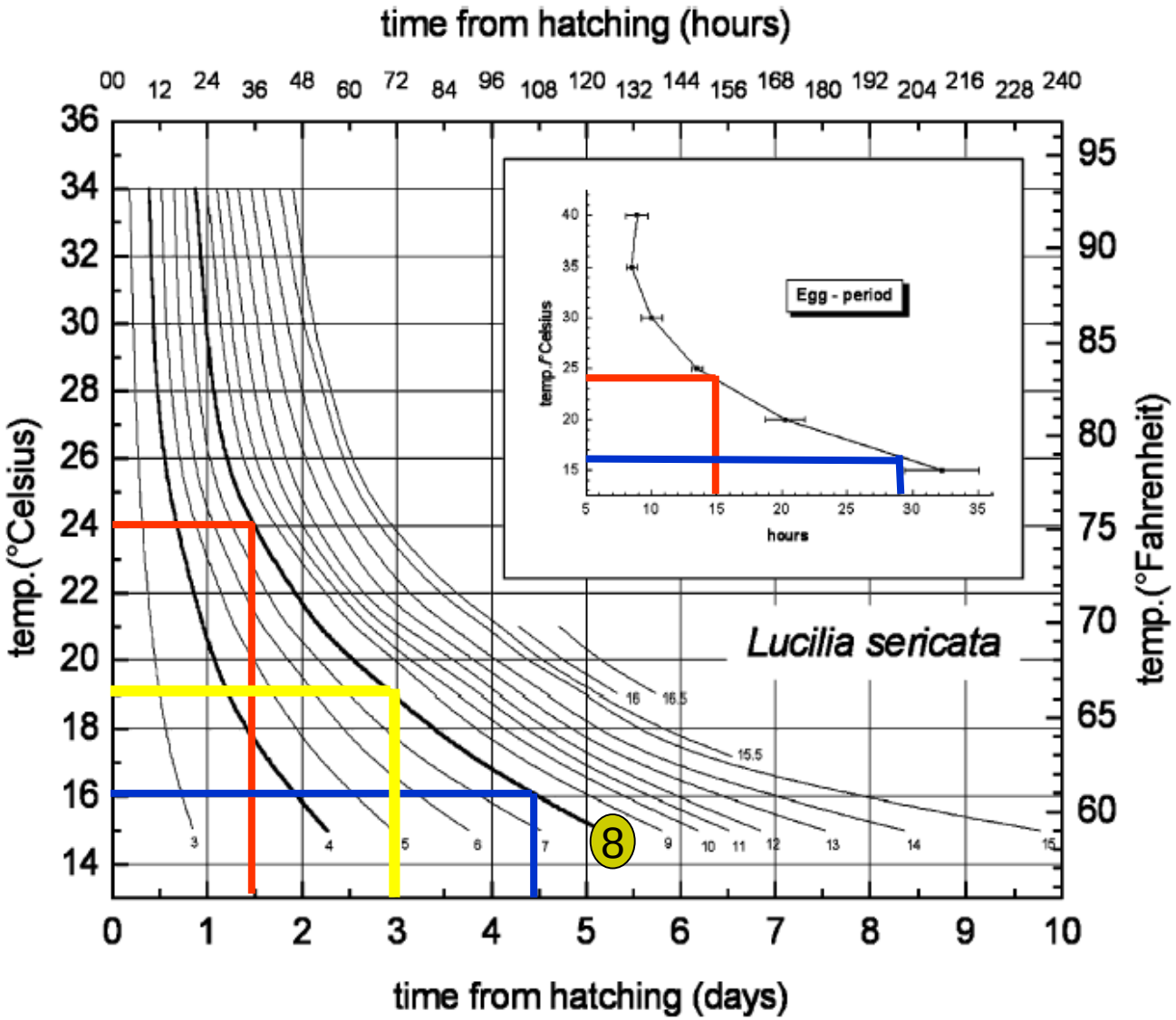
Grassberger M. & Reiter C. (For. Sci. Int. 2001)

Isomegalen Diagram for *Phaenicia* (= *Lucilia*) *sericata*



8 mm maggot
24 C daily max.
16 C daily min.

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Factors Affecting Decomposition

Geographical region (Bio-geoclimatic zone):

- It is one of the most important factors this has a major impact on the type, species; insects remain as well as their seasonal availability. It also affects the decomposition of the remain which in turn impact the insects that colonize them.
- The species involved in the sequential colonization of the remains and the time of their arrival vary from region to region.
- In tropical region as Hawaii, the first colonizers are *chrsomyia sp.* And *Sarcophaga sp.* (sarcophagidae) in contrast the first colonizers in south Carolina is *Cochlimyia sp.* (calliphoridae) geographical region obviously has a major effect on arrival times of different species of insects this means that data generated in one region shouldn't be used to determine time of death in a different region. Databases should be developed for every region in which insects are being used to determine time of death.

Factors Affecting Decomposition

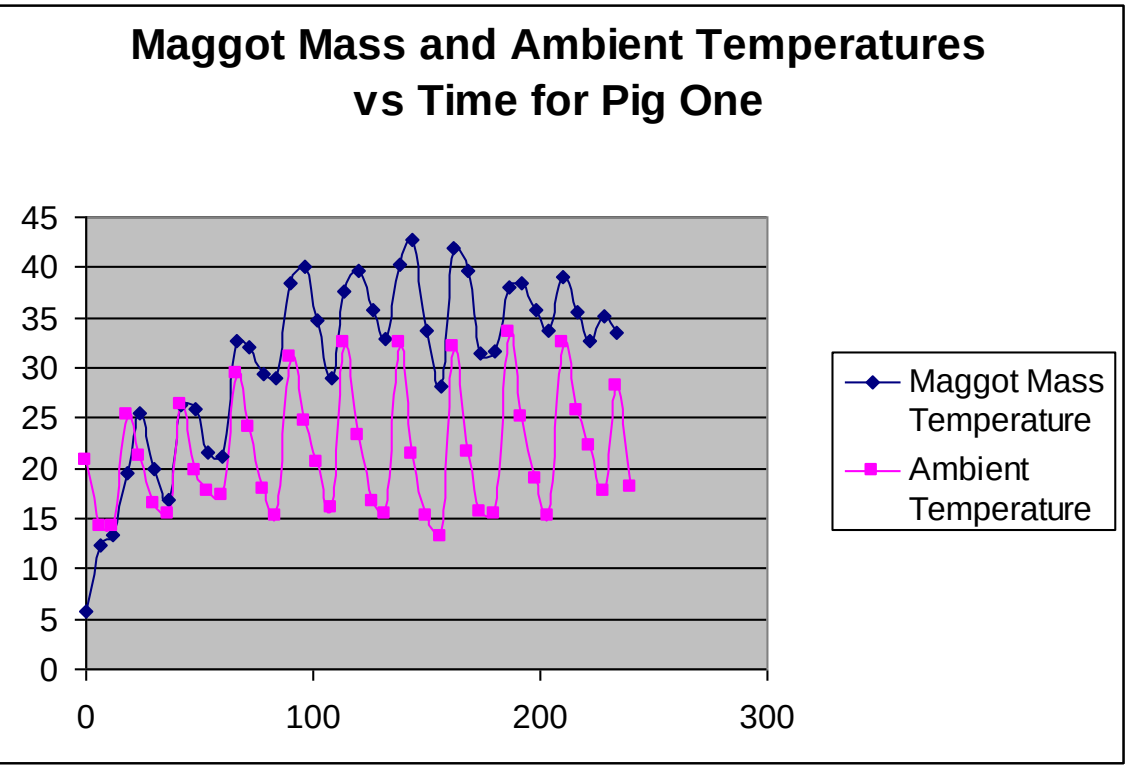
Season:

- It has a major impact on weather of the flora and the fauna of a region, thus, the faunal colonization of a body also is impacted.
- Many blow fly species vary in abundance depending on seasons.
- **For example:**
- *Lucilia coeruleivirids* and *Cochliomyia macelloria* were dominant in the warmer summer months from April to September, whereas *Calliphora livida* was dominated in the winter months, from October to March, where *Phormia regina* being found throughout the year.

Factors Affecting Decomposition

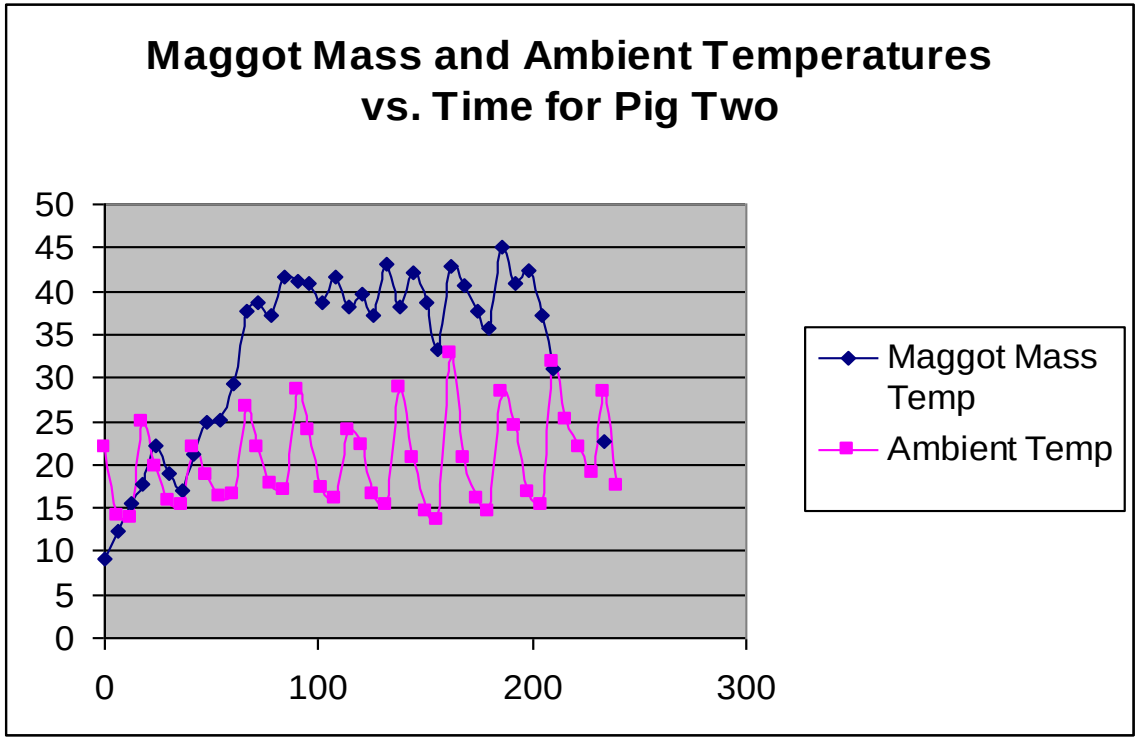
Sun exposure:

- The placement of the corpse has an effect on the decomposition and faunal colonization of the remains. The most obvious effect is that of sunlight and heat.
- Fly oviposition is strongly influenced by temperature and generally doesn't occur below 10 °C unless the substrate temperature has been influenced by solar radiation.
- Bodies found in direct sunlight will be warmer heating up more rapidly and decomposing faster, they will lose biomass more rapidly than bodies in shade and progress through decomposition stages faster.



Sunlit Pig

- The graph shows an elevation for maggot mass temperatures over ambient
- The fluctuation in ambient temperature induced elevated maggot activity which is consistent with other similar experiments.



Shaded Pig

- The ambient temperature for Pig 2 was more constant because it was in a shaded area.
- The temperatures for Pig 1 fluctuated more than those of Pig 2.

Factors Affecting Decomposition

Urban Vs. Rural:

- Some insect species are found in both urban and rural areas yet others are very specific to one or the other which indicate resource partitioning the early colonizing blow flies include rural, urban and ubiquitous species . This can be useful in forensic analysis as certain species of blow flies found on remains have been moved from an urban to a rural environment or vice versa, however caution must be exercised since only some species are found exclusively in one or other habitats, while many species can be collected in both such as *Phormia regina*.
- In an analysis of casework *Calliphora vomitria* was found exclusively in rural whereas species such as *Phormia sericata* were found exclusively in urban areas.

Factors Affecting Decomposition

Bodies found inside buildings:

- The public and police a like often believe that insect won't colonize remains inside a building. However, insect will colonize remains indoors as easily as outdoors. The succession will be limited by the species that can and will enter a dwelling and on how well the dwelling is sealed.
- Blow flies are strong fliers that can easily follow an odor plume over a long distance and can easily enter buildings.

Factors Affecting Decomposition

Burial:

- Disposal of the remains is often of paramount concern to a killer but a human body is difficult object to dispose of and commonly chosen method is burial bodies buried feloniously however rarely are deeply buried as burying a full sized human body at traditional 6 ft depth requires a great deal of work and time.
- The more time a criminal spends with the victim, the greater the chance that evidence will be transferred and also that the killer will be found with the remains.
- Therefore a hasty, shallow grave is usually all that is dug. Buried remains are still colonized by insects but burial influences the time required for insects to reach the remains, the sequence of colonization the species involved and the rate of decomposition.

Factors Affecting Decomposition

Scavenging:

- Scavengers other than insects are attracted to remains and can remove large quantities of flesh and even clothing this can have a major effect on the decomposition rate and consequent insect colonization.
- Vertebrate scavening "small rodents" occurred most commonly "shaded areas, deposite the color temperate. Pig carcasses situated at shaded site were scavenged and lost mass at the same rate as those in direct sun.
- Scavenging affecting the decomposition and insect colonization.
- Scavenger are common on remain acting as opportunistic predators of insects they may remove blow fly larvae
- **For example:**
- Fire ants *Solenopsis spp.* (Hymenoptera, Formicidae) which may remove significant number of blow fly eggs and larvae.

Factors Affecting Decomposition

Presence or absence of clothing:

- –Human victims are frequently clothed the majority of victims were completely or partially clothed. Clothed can be expected to have an effort on insect succession on a corpse as it affects the temperature and humidity of the remains the amount of shade and protection of the body provided.
- Most early instar larvae require liquid protein for survival as the clothing become saturated with decompositonal fluieds. It provides more sites for ovipostion than a nak ed corpse resulting in larger larval masses and hence faster decomposition.

Factors Affecting Decomposition

Submerged in water :

- Similar stages of decomposition takes place in water but an additional stage (floating decay stage) was noticed where the body rises to the water surface. At this point, besides aquatic insects such as midge (chironomid) larvae and invertebrates such as water snails, terrestrial insect species also colonize the body.
- This stage is the most obvious stage and tends to be the point at which a body is noticed and recovered from the water. The period of time after death when this takes place will depend on the temperature of the water.

Factors Affecting Decomposition

drug consumption:

- The stage of insects that feeds on the corpse can retain some types of drugs that had been consumed by the victim before he/she died and which may even have been the cause of death, these drugs may be recovered by analysing the insects and may include opiates, the barbiturate phenobarbital, benzodiazepines or their metabolites.
- For example, the length of time taken to complete individual larval stages in Sarcophaga was considerably longer, in contrast to those larvae which were not fed heroin. However, heroin has been shown to increase the rate at which other species of maggots grow, whilst increasing the duration of pupal development.

Factors Affecting Decomposition

drug consumption:

- Cocaine and one of its breakdown products has been found in small amounts in the puparium of Calliphoridae, so this drug is clearly sequestered in the larval body and retained in the next life stage.
- A correlation was observed between concentration of morphine in body tissues and that in the tissue of larvae of *Calliphora vicina* in the third instar.
- In *Lucilia sericata,* the post mortem interval could, be 24 hours longer in larvae feed on morphine.

Ecology of Decomposition

- Necrophages - the first species feeding on corpse tissue. Includes rue flies (Diptera) and beetles (Coleoptera).
- Omnivores - species such as ants, wasps, and some beetles that feed on both the corpse and associated maggots. Large populations of ominvores may slow the rate of corpse's decomposition by reducing populations of necrophagous species.
- Parasites and Predators - beetles, true flies and wasps that parasitize immature flies.
- Incidentals – pill bugs, spiders, mites, centipedes that use the corpse as an extension of their normal habitat

The Story Maggots Tell

- Blowfly maggots are of two forms: smooth maggots, and 'hairy' maggots.
- The smooth maggots belong to pioneer flies that are purely corpse feeders.
- 'Hairy' maggots will often feed on corpses, but they are also active predators that feed on smooth maggots.
- Because they are predators, the arrival of the secondary flies that produce hairy maggots is normally later than that of the pioneer maggots.
- Beetle maggots also tend to be predatory like the adult beetles.

THE END

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