Insidious insects invade

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Submitted for your approval

If you gentle readers are like yours truly then you have a soft spot in your hearts for giant bug movies. Intuitively we know that such creatures do not exist, (after all, if they did, then where are they?) but this does not diminish our scary enjoyment of them. Bug movies are more than a guilty pleasure for this Monster Kid Scientist, they are pure fun. The bigger the bug the badder the insect and more fun the film. The acronym, B.E.M, which stands for 'bug-eyed monsters', accurately describes these monsters of mayhem. As a group insects are an amazing success due mostly by the diversity of habitats in which they live. Though insects are most numerous in terrestrial environments such as deserts, forests, and grasslands they are also found in such diverse habitats as freshwater ponds, lakes, streams and wetlands. Insects are literally everywhere and insect films are as numerous as ants at a picnic.

The scary world of insects

The word 'insect' comes from the Latin, *insectum*, the origin of which means, "cut into sections". Insects are a class of hexapod invertebrates that have three parts or sections, a head, thorax, and abdomen. Characteristically, insects have an inelastic exoskeleton primarily made of chitin, a structural protein that does limit their growth (they need to molt to grow), three pairs of jointed legs (6 total), compound eyes, and one pair of antennae. Most insects are hatched from eggs and often the immature stages differ significantly from the adult stage. Adult insects move around by walking, flying, or sometimes swimming.

[So not to confuse you gentle readers, arachnids, such as spiders, ticks, and scorpions, all have 8 legs; insects have 6 legs.]

Entomology 101

Entomology is the study of insects and fans of bug movies know that entomology rocks! Bugs, or more accurately, insects, are the most dominant animals on Earth. Of the Phylum, Animalia, about 90% of all species are invertebrates and, of these, 80% are insects. There are close to 7 billion humans and there are about one million insects for each and every one of us. This makes an impressive total of $7x10^{15}$ insects! And, of these, most are ants. Insects have seemingly been around forever. Fossilized insects of impressive size have been found as far back as the Paleozoic Era (began 541 million years ago). Some fossilized giant dragonflies have been found with wingspans of 55-70cm (22-28 inches).

Insect stats

For these miniscule monsters of mighty mayhem it has been estimated that the total insect species to be around 8,750,000 of which about 1,025,000 have been identified and named so entomologists have a long way to go to characterize all insects. For comparison sake, there are about 4,809 species of mammals, including man, about 320,000 species of plants and about 35,000 species of fish. Insects clearly dominate.

In total, there are 24 Orders of insects, of which only 4 dominate. These 4 are, coleoptera (beetles; 300,000-400,000 species), diptera (flies; 90,000-150,000 species), hymenoptera (bees, ants, wasps; 100,000-125,000 species), and lepidoptera (butterflies; 110,000-120,000 species).

These six-legged insects walk with a tripedal gait, meaning they walk with their legs touching the ground in alternating triangles. As adults most insects are solitary though some, like bees and ants, are very social and live in well-organized colonies. Insects communicate with each other in many ways such as by sound (like crickets), pheromones (like ants and moths), and by light (some beetles).

Insect mutations

For insects to go from Lilliputians (small) to Brobdingnagians (big) will require some serious DNA and genetic modifications. These DNA mutations can result by exposure to high radiation (Them!), toxic dumps (Skeeter), or the mixing of contaminating DNA (The Fly). Films during the atomic 1950s focused on radiation mutations whereas those films from the 1990s and into the 21st Century focus on genetic mutations of the DNAge. From the perspective of this Monster Kid Scientist the 1950s atomic age mutations seemed more frightening at the time than genetic mutations during the 21st Century DNAge.

Even for their small size insects have complex traits and mutations do affect these too. Everything new must come from something old, meaning mutations come from already existing parts. So whatever biological structure, tissue, or organ that was already there then mutated into something else. Making something completely new without something to work from does not happen in biology.

Big Bad Bugs or Scaling issues

For big bugs (or all biology for that matter) size does matter. Absolute size cannot be looked at in isolation since size does affect all aspects of body biology. Furthermore, size cannot be treated in isolation since every organism influences those around it. Biological size is referred to as “scaling” and scaling is related to geometry. In biology, geometry is a functional relationship. Geometry is length, area, and volume and all are proportional to each other. As size changes the length, area, and volume (or biomass) proportionally increase too. If something

is three times normal size then the volume would proportionally increase 27 times! (Volumes are proportional to length cubed so three times normal size is 3x3x3 or 3^3=27.) If an ant or a grasshopper were 10 times normal size then the volume would increase a whopping 1000 times (10x10x10 or 10^3=1000)! Simply stated, if size changes then volume changes faster. This is important because of the physical forces involved in larger sizes. For example, inertia is related to size and mass. If a fly flies into a window no harm to the fly due to small inertia but if a bird flies into a window the bird could break its neck due to a larger inertia. The bigger the size the more the inertia so even if a giant bug hits something more than likely the bug will suffer some damage.

Volume is also related to weight that can impact on muscle and bone strength. Since insects, small or large, do not have bones then other body parts must function in that capacity to provide strength and this puts mechanical stress on the rigid body exoskeleton. Routine locomotion could overstress the mechanical limits of large exoskeletons causing breakage. Exoskeletons and all other elements would have to proportionately enlarge at the same pace and provide appropriate mechanical strength. Increase in size and weight could mean a change in posture. Are limbs bent or straight? When volume is in excess of the ability to carry the weight then buckling occurs with the legs. With the excessive volume there is too much pressure and mechanical strain for the insect legs to hold the weight, not to mention any kind of movement. Also, with the larger surface area of bigger insects then dehydration due to water loss is also proportional to size. Where do these large bugs get enough water (especially the ants in THEM! who live in the desert)? Furthermore, large animals must consume large quantities of food every day so they hunt for appropriate food sources.

In addition to the size of insects there is also the number of insects to consider. Individually, insects can be easily taken care of. However, en masse, they can be a natural horror and a formidable foe. One large ant can ruin your day as well as a large colony of small ants! When locusts and bees swarm they can be just as deadly as their big relatives. This is all due to their social nature. Whether a single big bug, colonies of insects, or a swarm, all can be deadly.

Respiration

Like all animals on Earth we depend upon oxygen for respiration and this is no different for insects. However, since insects do not have lungs (and therefore no red blood cells, RBCs) they must acquire oxygen by different means. And this is what limits insects size, their respiration. Oxygen for respiration (from the air) is transported in insects, either by diffusion or changes in internal pressure (through body motion or hemolymph circulation), through tiny holes in their bodies, called spiracles, then through tracheae, an internal system of air-filled tubes, to within a few cell diameters to each individual cell. The tiniest tubes, called tracheoles, are about 1um (10^{-6} meters) in diameter. Air (oxygen) movement is done by rapid cycles of tracheal compression and expansion in the thorax and head

areas. The passage of air into the trachea is regulated by the spiracles. In total, the tracheal system provides a large surface area for the permeability and diffusion of oxygen and at their size, just enough without the need for lungs.

By taking into consideration oxygen consumption, diffusion rates, and tracheal size then the physical limits of oxygen diffusion would be limited to no more than 3millimeters. Ventilation or airflow can make this more efficient along with motions of the body and churning of internal organs. Even so, the tracheal system limits the size insects can achieve. Oxygen diffusion, the ability to get oxygen from the air, is good over distances of millimeters but not more than a few centimeters so insects shall forever remain small.

During the Carboniferous Era (about 300 million years ago), when the oxygen content of the atmosphere was significantly higher than it is now, insects were much larger, some as large as a meter, because of the oxygen-rich air enabling them to be larger. The higher percentage of oxygen in the air means easier diffusion into insect organs. As an insect increases in size the demand for oxygen will also proportionately increase too. When the oxygen content of the air lowered to current levels then insect size also lowered.

It may bug you but it insects me!
To many, insects are seen as nothing other than pests and there have been many attempts to control them through a variety of pest management means, such as insecticides. Insects damage crops, trees, eat homes, infect, and can even kill. In spite of the billions of dollars spent every year on pest management no single species of insect has been purposely eradicated; at best, just controlled. On the other hand many insects are beneficial such as those that help pollinate, consume carrion, make silk (silkworm), and in some cultures serve as a staple food source.

Chemical communication
In insects, chemoreception is their physiological response to taste and smell. A chemical stimulus acts as a signal to regulate insect activity, and indicate friend or foe, attract or repel. In other words, a signal that translates as ‘is this something to eat or will it eat me’. All of us are familiar with the ‘trail’ an ant leaves which is a form of chemoreception that they sense and follow. Many of these chemical stimuli act as pheromones to insects that in turn modify and affect various behaviors and their responses. Furthermore, social insects have developed various chemical scents to use as communication.

The sounds of insects
Insects make sounds, both high and low frequency, primarily by physically moving appendages, mostly legs and wings. In grasshoppers and crickets this sound is called stridulation. Cicadas make the loudest insect sound by amplifying a combination of musculature and body movements. The African cicada sound has been measured at 106 decibels, loud indeed. Some species of

beetles make low frequency sounds primarily made by the insect's body movements, located in body muscles and joints. Insects can also amplify these sounds that can warn or communicate with other insects.

Insects also have typanal organs that sense sounds and vibrations on surfaces, essentially serving the same purpose as ears. Communication amongst insects takes place primarily through vibrations. Sound does not travel that far and since most of these sounds are blocked by the dense environment of foliage where insects live they use these vibrations instead to communicate and to attract mates.

Irrespective of all those noisy crickets, katydids, and cicadas chirping away very few insects actually use sound as communication. In addition to the above, just a few other species, like the moth and fly, produce sounds to communicate. In other words, they use sound to send information. For example, the drosophila fly produces two sounds, a pulse and a sine, through wing vibrations, one sound for mating and the other for defense.

Scary swarming

Locusts and bees swarm and this is a collective behavior. During swarming the insects aggregate together and move or migrate about as one. Swarming behavior follows simple mathematical rules that help predict their actions. Some swarms can travel great distances and cause great damage. It has been suggested that swarming behavior is a response to overcrowding. When bees swarm they at first do not fly far from their nest and typically find a new tree or branch nearby. Bee scouts then search for a new location. After finding a suitable place the swarm then flies to the new spot.

Insect poisons & toxins

Many insects have poisons or toxins that can harm or kill other species. These toxins are used for both defense and to capture others for food and many of these toxins are protein based. Just so you scary readers know the most toxic poison of all insects is from the harvester ant, *Pogonomyrmex maricopa*.

What's behind the curtain

Here is a brief list of things we don't think about but are important for bug movies: insect life cycles, metabolism, etymology (origins), development, phylogeny and evolution, diversity, morphology and physiology, reproduction and development, senses and communication, social behavior, locomotion, ecology, and relationship to humans (both as pests and beneficial for food and pollination).

THE FILMS (or insect movies that bug us)

Insect films were popular during the 1950s with a minor resurgence during the 1990s. And then another resurgence during the early part of the 21st Century, mostly due to the ease of computer generated images (CGI). There are several

examples in each of the key insect categories (ant, bee, cockroach, fly, grasshopper, mantis, wasp, and mosquito) so we limit ourselves to just one example of each.

THEM! (1954)
Brief synopsis. After a series of deaths in the New Mexico desert authorities are called in to investigate. It was determined these deaths were caused by giant, mutated ants (gi-ants!), resulting from the Trinity atomic bomb testing at Alamogordo in 1945. Entomologists worked with the army and FBI in locating the nest colony that was eventually found in the sewer system of Los Angeles. The nest and the colony queen were destroyed.

Ants belong to the Order, Hymenoptera, along with bees and wasps, and so far about 12,500 species of ants (of an estimated 22,000) have been described. Most species are found in the tropics, Africa, and Asia. Since ants are eusocial animals they form colonies that operate as a unified group that can range in size from a few dozen to millions. Such large colonies have castes or divisions of labor consisting of workers, soldiers, drones, and other specialized groups. Typically, one fertile female, the queen, is in charge.

By and large, ants have colonized all lands and ecosystems on earth except Antarctica. It has been estimated that about 15-25% of earth's biomass is made up of ants! Their successful dominance on earth is primarily due to their social nature and ability to adapt to their environments. Ants are herbivores, predators, and scavengers. On the down side ants are a pest and can damage crops and invade buildings.

To maintain the size of the ants seen in the film, about 8-12 feet long, they will have to increase the number of tracheal tubes in order to maintain a sufficient oxygen supply to their cells. Also, in the flight muscles of a queen ant the oxygen demand will be high, especially when they are flying, so for these queens the tips of the micro trachaea actually have to penetrate cell membranes delivering oxygen directly to mitochondria, the power source of every cell. Without this feature these gi-ant queens would not be able to fly since they would not be able to generate enough energy for flight. In this film a queen ant flies from New Mexico all the way to the sewers of Los Angeles so the oxygen demand for those flight muscles would have been extreme.

Ant morphology
Normal ant size typically varies between 0.75 to about 50 millimeters (0.030 to 2.0 inches) with the largest being 6 centimeters (2.4in) long. Most ants are red or black but some species are green. Ants have elbowed antennae ("feelers") and distinctive slender "waists", called a petiole, which separate the thorax (mesosoma) from the abdomen (metasoma).

Ants have an exoskeleton that serves as an external body covering that provides a protective casing and to attach internal muscles. Ant nervous system consists of a ventral nerve cord that runs the length of the body with a few branches along the length that reaches other areas of the body.

Ants have compound eyes composed of many tiny lenses that primarily function as motion sensors and not on detail. These compound eyes are also sensitive to levels of light. Ant antennae have sensory organs that can detect air currents, chemicals, and vibrations. Antennae are also used to send and receive signals ("shoot the antennae", shouts Dr. Medford). Ants have mandibles or jaws that are quite strong that can carry and defend. All six ant legs are attached to the thorax or mesosoma and usually end in a hooked claw structure. Only queens and reproductive males have wings and after mating the queen looses her wings leaving visible stubs.

The ant abdomen, or metasoma holds the important internal organs for reproduction, excretion, and tracheae respiration. The worker ants that are not involved in egg-laying have modified these structures into stings. If ant eggs are fertilized then the progeny will be female but if the eggs are not fertilized then the progeny will be male. Queens and workers are both female, though of different casts. Winged male ants are called drones. Some queen ants can live up to 30 years so ant colonies can be long-lived. Worker ants typically live between 1-3 years. This is why the military was so intent on finding the nest in Los Angeles because they were fearful of the queen's ability to live long and make more colonies.

Ants communicate with each other with pheromones (chemical signals), sounds, and touch. These pheromone chemical signals are produced by a variety of glands in the ant. Transferring information via pheromones is called trophallaxis. Ants leave pheromone trails on the ground so others can readily follow. When a forager finds a food source a trail is marked by pheromones on the way back to the colony. Also, crushed ants leave a pheromone "alarm/attack" signal that other ants respond to so their communication can be quite complex indeed. Ants "smell" with their antennae and with two then direction and intensity of scents can be discerned. When interacting with other ants they frequently use touch, mostly with their antennae.

Ant nests & navigation

Though many insect species build complex nests it is the ant that surpasses them all. Ant nests tend to be permanent and can be subterranean, in trees, under stones, under and inside logs, pretty much everywhere. When ants forage they can go to distances up to 200 meters away from their colony nest and using pheromones can easily find their way back, even in the dark.

It's all in the stinger

In the film, THEM!, we first learn of the ants by what they do naturally, look for food. In this case, sugar. Secondly, when a local coroner examines the body of a man unknowingly killed by a gi-ant he says, “Old man Johnson could have died any way of five ways. Neck and back broken, chest was crushed, skull fractured, and here’s one for Sherlock Holmes. There was enough formic acid in him to kill 20 men.” Ants primarily defend themselves by biting and stinging by injecting or spraying toxic chemicals, the major one being formic acid. Formic acid is a one-carbon compound (CH_4O_2) with a very distinctive odor. Humans have a difficult time metabolizing one-carbon compounds, which is why they can cause a lot of pain and in sufficient quantities even death. The little Ellison girl was snapped out of her trance-like state by simply smelling formic acid and she screamed, “Them…them!”

It’s only a name

The taxonomic identification of the gi-ants in the film deserves comment. In the film, the entomology expert, “world famous myrmycologist”, Dr. Medford, boldly states after looking at one of the gi-ants, “*Camponotus vicinus*. One of the family, Formicidae…an ant. A fantastic mutation. Probably caused by lingering mutations from the first atomic bomb.” Ants of the genus, *Camponotus*, are carpenter ants and are primarily found around forest environments of decaying or hollow wood and not the hot and arid New Mexico desert as seen in this film. In addition, *Camponotus* species are polymorphic workers meaning their size is highly variable and body proportions would vary too. Workers have a much larger head than others. Lastly, *C. vicinus* heads are always completely black. The Camponotus ants seen in the film do not fit this description. It should also be noted that Camponotus ants do not have stingers which those in the film do.

THE BEGINNING OF THE END (1957)

Brief synopsis. A small town in Illinois, Ludlow, population 150, was completely wiped out by a swarm of giant, mutated grasshoppers. The military was called in but conventional weapons seem useless. The grasshoppers invade Chicago and eventually scientists discover sound can drive them into Lake Michigan where they drowned.

Grasshoppers are in the Order, Orthoptera, which also includes crickets and katydids, and fossils have been found that date back to the Triassic period, 250 million years ago. Grasshoppers have had a long history with humans and have even changed the course of history as the plague and famine events described in the Bible and the Koran. Grasshoppers have been featured in both literature and art and in some cultures are considered fine cuisine. Like many insects grasshoppers too are good at camouflage. Female grasshoppers are typically larger than males.

The End of the Beginning

Though primarily ground-based, grasshoppers use their powerful hind legs that allows them to leap great distances or to launch themselves for a short flying distance. When high in number (in the millions) some grasshopper species swarm, change color, and are therefore called locusts. When swarming, locusts can completely destroy crops over wide areas. The largest recorded swarm, in 1875, was 1,800 miles long and 110 miles wide and composed of an estimated 3.5 trillion locusts!!

For food, they are polyphagous plant-eaters, meaning they more or less eat any plant, and prefer cereals, vegetables, and pasture grasses. A locus can eat its own weight (about 2grams) each day so simple math shows that one million locusts can consume one ton of food each day and large swarms can consume over 100,000 tons a day! Swarming behavior has been associated with elevated levels of serotonin, a neurotransmitter hormone that helps regulate gut movements. Increased serotonin levels bring about some camouflage color change and an increase in appetite.

Ahead to the abdomen said the thorax
Grasshoppers have typical insect body parts of a head, thorax, and abdomen. On the vertically aligned head are the compound eyes that provide an all around vision view. Grasshopper antennae are sensitive to both touch and smell. The mouth parts or jaws are modified for chewing. The outer areas of their bodies are made of overlapping plates of chitin. The three pairs of legs and the two pairs of wings are attached to the thorax. Grasshoppers have both forewings that are narrow and leathery and hind wings that are large and membranous. At the ends of the legs are claws, very useful for gripping. Also on the thorax is the tympanal organ or hearing system. The large compound eyes on each side of the head have a broad vision field and can detect movements, shapes, colors, and distances. Like other insects respiration in grasshoppers is done via air-filled tracheae tubes that open as the thorax and abdomen through spiracles.

The art of jumping
What really separates grasshoppers from others are their powerful hind legs. The larger grasshoppers have been measured to jump about a meter (20 body lengths) without the aid of their wings. They position their back legs against a surface and push away with high force and thrust propelling them into the air. The takeoff velocity determines the range of the jump. (Note: due to a fundamental property of muscle it cannot contract with both high force and high velocity at the same time; grasshoppers overcome this by using catapult-like leg action that amplifies the mechanical power of muscle.)

The grasshopper jump is a three-stage process. The process begins when the grasshopper flexes the lower leg against the upper leg. The second stage is when the muscles co-contract building up force by using mechanical advantage which can take up to a half a second. The third stage is when the elastic muscles relax in a catapult-like manner that releases the built up energy of

muscle contraction. So, muscle contraction energy is stored and then rapidly relaxed releasing mechanical energy.

A sound idea or finding the frequency
It is the male grasshoppers that "sing" or stridulate more than the females. These stridulation songs are a form of communication and are primarily made by males to attract females. On grasshopper legs are rows of pegs that when rubbed together against the edges of the forewings provide their characteristic sound. This concept is used by Dr. Wainwright, an entomologist in the film, to deduce which sound frequency affected the grasshoppers. He goes about this is a scientific systematic matter over a wide range of frequencies until he found one that affected the grasshopper they had captured. For our purposes, on the front end of the abdomen of the grasshoppers is a pair of tympanal organs that detect sound. It is these tympanal organs that detected the sound that attracted them to Lake Michigan to drown.

Growing a grasshopper
The explanation given by Dr. Wainwright as to the cause of the mutated grasshoppers is the insects somehow got into the small radioactive samples stored at his lab and this mutated the grasshopper DNA into the giants they become. He says, "Some locusts must have gotten into the lab and they ate some of the plants and radioactive plant food. Well, their cell division accelerated immediately, that is, they started to grow abnormally fast. They had to have a constant food supply to sustain this growth." In the film, these locusts are the size of a bus. If a locust that large jumped 20 times its length, or fell off Chicago skyscrapers, then when it landed there would be a splat and a dead insect due to the inertia and momentum of over a ton of bug hitting the ground.

When asked why Wainwright, an entomologist, is working with plants he explains, "The existence and development of plants and insects are closely related. They're highly dependent upon one another. As a plain matter of fact, one couldn't live without the other." Very true.

It was noted that the giant locusts could not fly since their wings did not develop. Therefore, they must crawl or jump to move. Chemical insecticides ("chlordane") were tried but did not work due to the large size of the locusts. (Note: chlordane or chlordan was used as an insect pesticide until 1988 when it was banned since it does affect human health and the environment.)

In the film, the grasshoppers have a "high pitch screech" used to communicate amongst themselves. Wainwright uses the natural galvanic responses to test which sound frequency will attract the locusts (giving a locust a polygraph test, using a Berkeley Psychograph, which is a lie detector). Wainwright says, "Up to now we've been using a filtered signal and it hasn't worked. But its just possible the hearing apparatus of the locust can detect harmonic frequencies above the human range." After a successful attempt, Wainwright uses their attraction to

mating calls by using sound, Pied Piper-like, to lure them into Lake Michigan where they drowned. A broadcast amplifier with oscillation frequency was used to attract the locusts to the lake.

THE DEADLY MANTIS (1957)
Brief synopsis. A prehistoric mantis, frozen in arctic ice, thawed making its way down from the artic region to New York causing much mayhem along the way. The mantis eventually made its way into the Manhattan Tunnel in New York where it was killed.

Mantids are in the Order, Mantodea. There are over 2400 species of mantids and they are distributed worldwide though predominate in arid habitats. They are characterized by having triangular heads with bulging eyes and flexible necks. Some have wings and some do not but all have elongated spiked forelegs that are efficient for capturing and gripping prey. Their upright posture with folded forearms gave rise to their name, praying mantis. Mantids are predators and many of them simply ambush their prey.

Due to the shape of their head and the lateral location of their eyes they have stereo vision (meaning high resolution) and can readily track prey by sight. Since hunting prey relies on vision mantids are diurnal (out in the daylight). Those mantids that are out at night (nocturnal) have an auditory thoracic organ that helps them get around at night. For example, this organ can detect bat echolocation signals thereby giving mantids the ability to evade being eaten by bats.

In a defensive posture, mantids stand up, spread their forelegs, and fan out their wings, making them seem larger and more threatening. If the threat continues the mantis then strikes with its forelegs followed by bites, if necessary. Perhaps somewhat surprisingly, mantids have a high morphological resemblance to cockroaches.

Praying for the Mantis
The mantis in this film is considered a natural insect that is naturally large from prehistoric times and not due to some radiation-induced mutation. This large insect was frozen in ice in prehistoric times that was thawed in modern times. (What it was doing in the cold arctic region is anyone's guess.) For an animal this size scaling issues would limit movement and most likely the legs would buckle due to the excessive weight, most of which would be fluid in the thorax. When this mantis flies it uses all 4 of its wings with a "loud droning sound."

Dr. Nedrick Jackson, Curator of the Department of Paleontology at the Museum of Natural History, was asked by the army to evaluate an "appendage (that) comes from some creature." The 5 foot long, "mottled green" appendage is a "hook" or spur. Upon scaling up the size of the spur and looking for comparisons

Jackson correctly identified it as coming from a giant praying mantis. As Jackson describes the spur, "…more like gristle or cartilage. And a structure as large as this would have to serve a specialized purpose in order to be cartilaginous." An analysis of this gristle fluid showed that no "red corpuscles" are present indicative of insect origin.

THE FLY (1958)

Brief synopsis. A scientist at "Delambre Freres Electronics Montreal Ltd" built a matter transfer machine that disintegrates and integrates and in an attempt to transfer himself a fly inadvertently got into the machine and was transferred along with him. As a result both the fly DNA and the scientist DNA were mixed resulting in both a fly-man hybrid and a man-fly hybrid. The scientist's wife eventually helped him destroy himself.

Fly fun facts

Flies belong to the Order, Diptera, and it has been estimated there are over a million different species of flies, though only about 125,000 have been discovered. Flies are found all over the world, except Antarctica. Flies have been known to populate such diverse environments as hot springs, geysers, saline pools, glaciers, and septic tanks. Common types of flies include, house flies, blowflies, mosquitoes, gnats, and fruit flies. A curious thing about flies is they only have a single pair of wings to fly where as most other flying insects have multiple pairs of wings. These single pair of wings gives them impressive aerodynamic maneuverability in flight, as anyone can attest who has tried to swat one as it flies by (and most likely missed); flies have remarkable yaw, roll, and sideways transitions and combined with their ability to use motion parallax makes them a difficult to target to hit. Though we all consider flies as pests (house flies spread food-borne diseases) they do serve an important ecological function, namely, their role as pollinators, and are only second to bees in this role. Also, fruit flies, in particular, *Drosophila melanogaster*, are used as a model organism in much research. The largest fly, *Gauromydas heros*, can be up to 7cm (2.8 inches) in length whereas the smallest, *Euryplatea nanaknihali*, is only 0.4cm long (0.016 inches), smaller than a grain of salt. As adults, flies have short life spans and live just long enough to mate and lay eggs.

Your fly is open

Flies are known for their large compound eyes on a mobile head; these eyes have motion-sensitive neurons. Their mouth parts are made for piercing and sucking (like black flies and mosquitoes) or for lapping and sucking (most others). On fly feet are claws and pads that allow them to cling to just about any surface, no matter how smooth. On the head of flies are their antennae and mouth parts (labrum, labium, mandible, and maxilla). The thorax has the wings (and flight muscles). On the bottom of fly feet are chemoreceptors that respond to smell and mechanoreceptors that respond to touch. These, combined with gustatory (taste) receptors, enable flies to taste their food while walking on it.

Help Meeeee!
The fly that got mixed with Andre is described as a “bluebottle fly”, a common house fly, also known as the blowfly, and is the common name for the species, *Chrysomya megacephala*. This species is found throughout the northern hemisphere. Since our titular hero was transformed by a bluebottle fly its nomenclature seems appropriate: Kingdom: Animalia; Phylum: Arthropoda; Class: Insecta; Order: Diptera; Family: Calliphoridae; Subfamily: Calliphorinae; Genus: *Chrysomya*; Species: *megacephala*. Bluebottle flies primarily feed on nectar and adults are also pollinators. Bluebottle flies have a characteristic bright blue metallic abdomen with black markings and are covered with black bristle-like hairs. Its antennae are short. The now final, “Help meee, help meeeee!” high pitched scream of the fly-human about to be eaten by a spider has become iconic and no one who sees or hears it will forget it.

A leg up
Over the course of several days of the films time both the fly-human and the human-fly change. The first time we saw the small fly-human, the boy Phillipe comments, “Its head is white instead of black and it has a funny sort of leg.” Then later he sees it again and says, “it’s grown quite a lot” compared to the first time he saw it. And, Andre, the human-fly, has also gone through growth changes and is seen deteriorating in mental clarity, becoming more fly like, and says so via typewriter and on chalkboard. In support of this we see Andre type, “cant think easy since morning brain says strange things now feel my will going always strain very difficult to think straight”.

WASP WOMAN (1959)
Brief synopsis. The head of a cosmetics firm, Janice Starlin, wants to improve her looks and beauty so she has one of her scientists prepare an enzyme extract from wasp royal jelly that brings back youth. Unfortunately, after taking the extract the woman morphs into the wasp woman and is eventually killed.

A wasp belongs to the Order, Hymenoptera, the same as bees and ants and like their cousins wasps also build nests and swarm. The most common known wasps are the yellow jackets and hornets. There are tens of thousands of wasp species and they populate all parts of the world except the polar regions. Some wasps are predators and have been useful in pest control. Only about 2% of all insects are social and wasps are one of the social groups (along with ants and bees). It is of interest that at the beginning and end of the film the credits are shown over a bee colony and not wasps.

Wasp did you say?
The wasp, *Megaphragma mymaripenne*, has a brain with only 4,600 neurons and when compared to the housefly (340,000 neurons) and bees (850,000 neurons), that have considerably more, the wasp comes off as the cretin of hymenopteras.

Even with such few neurons these wasps are still able to fly, eat, and find hosts for eggs. It is tempting to speculate that Starlin's brain neurons atrophied during her metamorphosis into a wasp so all she thought about was eating. After all, Starlin did appear to have multiple headaches during her transformations into the wasp woman so her brain may have atrophied as a result.

Starlin hires wasp expert, Dr. Zinthrop, who is working on making royal jelly from queen wasps in order to test the effects of an "enzyme extract" of the jelly on ageing. As Zinthrop says, "slow the process of ageing. Soon I will be able to reverse it". A workmate says, "claims [Zinthrop] can stimulate the processes of rejuvenation through the use of enzymes extracted from wasps."

Zinthrop's extract

For his work, Zinthrop extracts a special anti-ageing compound from the royal jelly of the queen wasp. Since this extract is protein in nature it must be an injectable. An enzyme called, telomerase, has been shown to affect the process of ageing and maybe Zinthrop has some of this in his extract. He uses the word enzyme (which is a protein that does work; all enzymes are proteins) so for an enzyme extract to be effective this extract must alter the expression of DNA in order to get the wasp conversion. There are many enzymes that can do this so maybe Zinthrop has something real. Furthermore, for work at the time (1959) Zinthrop's purification techniques were limited so maybe he had some contaminating wasp DNA in his extract that he did not know about and this is what caused all the mayhem of Janice Starlin's mutation to a wasp.

The wispy wasp

Physically, the wasp woman has a hairy, bulbous head with two prominent antennae protruding from the side forehead area. (The hairy head and antennae make it look like a lodge hat!) The compound eyes bulge with a seemingly looking human nose. The wasp woman uses the tips of her 'hands' to puncture her victim's neck and then uses her mandibles to suck blood. Typically, wasps use their stingers but the wasp woman goes the way of many other insects in using her deadly bite. Without a stinger then perhaps the name 'wasp woman' may be a misnomer. Nevertheless, her transformations come on quickly so they must be hormonal based, though ultimately controlled by what DNA, both human and wasp, may be interacting and mixing from the enzyme extract injections. Lastly, as the wasp woman, Starlin still wears her jewelry, such as her necklaces.

Royal Jelly

Royal jelly is a secretion that is used in the nutrition of honey bee larvae, including adult queens. This jelly is secreted from the hypopharynx glands of worker bees and fed to all larvae in a colony. Royal jelly is composed of about 67% water, 12.5% protein, 11% sugar, 5% fatty acids, 2-3% of a small organic acid (10-hydroxy-2-decenoic acid), and trace minerals. This jelly also contains some vitamin B_5, B_6, and some C, but no fat-soluble vitamins (A, D, E, & K). Zinthrop was interested in the 12.5% protein component that would contain his

“enzyme extract” (remember, enzymes are proteins). In particular, there is a single protein in royal jelly, called royalactin, which has been shown to cause a bee to develop into a queen. Royalactin could be a component of his enzyme extract. According to Zinthrop, wasp royal jelly is a more powerful form of the jelly so maybe it contains more active enzymes.

THE DEADLY BEES (1966)

Brief synopsis. An ailing starlet is sent to a remote island to recover. An island neighbor has discovered the “smell of fear” and uses it to control a lethal swarm of killer bees. Those who have the smell of fear on them, willingly or unwillingly, are attacked by the bees and killed.

Phantom of the ‘Optera’

Bees belong to the Order, Hymenoptera (same as ants and wasps), and are primarily known for their roles in pollination and making honey and beeswax. There are about 20,000 known species of bees and they are found everywhere except Antarctica. Bees feed primarily on nectar (an energy source) and pollen (a protein and other nutrient source). The pollen is primarily used as food for larvae. Bees have played a major role in human mythology and folklore and are also mentioned in the Bible and the Koran.

Plants, including most crops, are pollinated due to bees. Many farmers also have bee houses (apiaries) on their land to help pollination and bee keeping is called apiculture. On “Seagull Island” in the film there are two apiaries.

Swar-ming the Merciles

All bees swarm which is a process when a new colony is formed. In each new swarm a queen bee leaves a colony and a large number of worker bees, from thousands to tens of thousands, usually about 60% of the original hive, leave with her and swarm to a new colony. Swarming is a natural process for reproduction when the swarm can divide into smaller colonies and subsequently grow into larger ones.

Adrenaline vs Epinephrine

After “years of work” one of the beekeepers in the film was able to train his bees to follow a particular scent, in this case, adrenaline, referred to as the “smell of fear”. For “years of work” would imply multiple generations of bees were studied so whatever was learned must have been passed on genetically to the next generation of bees (most unlikely). As described by a beekeeper, adrenaline is “a chemical suddenly released into the bloodstream carried to the surface by the sweat glands in the form of ammonia. All animals and insects, especially bees, are strongly attracted, and sometimes aggravated, by this odor.” Astonishingly, he has trained swarming bees to be attracted to this scent. Adrenaline is derived from the amino acid, tryptophan. There is one nitrogen atom (the main component of ammonia or NH_3) in the adrenaline hormone molecule and it is

difficult to imagine a scenario whereby this single nitrogen can escape the body via sweat glands in the form of ammonia and subsequently attracting swarms of bees. (read: it won't happen)

Adrenaline, also called epinephrine, is a hormone secreted by the adrenal glands, especially in conditions of stress, which increases rates of blood circulation, breathing, carbohydrate metabolism (for energy), and preparing muscles for exertion. None of this is related to ammonia being secreted by sweat glands.

Busy as a bee

As the starlet in the film asks, "How can bees be sent?", meaning, what signal is there to alter bee behavior and make them purposely go somewhere? This method was described as, "concentrate 'smell of fear', get it on a victim, no person would be safe." With this method, apparently bee swarms can be sent anywhere and attack anyone. The starlet touches a chemical coated light switch and she subsequently rubs the chemical on her clothes. Later, another woman takes the clothes to be cleaned and while walking she is attacked by a swarm of bees attracted to the chemical. These "trained" bees are excited by the smell of fear and these 'fear-o-mones' (pheromones) are the chemical signals bees use in communication with each other to swarm. And to swarm a queen bee must be involved.

SKEETER (1993)

Brief synopsis. Drum barrels carrying toxic waste were stored in an abandoned mine. Mosquitos exposed to leaked toxins from the barrels developed into larger versions about the size of a blue jay bird. These large mosquitos attacked all animals including cows, horses, dogs, and man. Animals bitten by these mosquitoes had large welts on their bodies and many died as a result. The mosquito nest was burned.

Mosquitos belong to the Order, Diptera, family Culicidae and are related to flies. Mosquitos have a long tube-like mouth part called a proboscis that pierces the skin of a host to remove blood. (The word, "mosquito" is Spanish for 'little fly'.) There are over 3,500 species of mosquitos. You scary readers should know that only female mosquitos suck blood whereas males feed mostly on plant nectar so if a mosquito lands on you looking for a meal this animal is a female. Females primarily feed off of amphibians, birds, mammals, and reptiles. In most cases the amount of blood taken is unnoticeable to the victim.

The deadliest of them all

It may surprise some of you scary readers but the deadliest animal on Earth is the mosquito. Mosquitos can kill other animals that can be up to 5000 times their size! Mosquitos, such as the *Aedes egypti* and *Anopheles gambiae*, the ones that carry malaria and Zika virus, are the vampires of the insect world, and are

the species mostly associated with the vector spread of disease. Like Dracula, they only live on blood meals. Due to mosquito saliva from a bite often an irritating rash or welt is left after their feeding that can be annoying. That in itself, though irritating, is not really serious. What is deadly serious is that many mosquitos are vectors of disease (the most common is malaria). In this way, pathogens are readily passed from human to human through mosquito bites. Other diseases carried by mosquitos that can be passed on by their bites are dengue fever, yellow fever, and West Nile virus. With all of these they make the mosquito the most deadly animal of all.

Adult females of most mosquito species lay their eggs in stagnant water. In this film we see some very large mosquito eggs growing in a spilled broth of stagnant toxin filled water. This toxic environment mutated mosquito DNA causing them to grow into larger versions. Most normal adult female mosquitoes have a life span between a week and several months. Males typically live for about 5-7 days and feed on nectar. All mosquitoes have a head, thorax, and abdomen. On the head are the antennae that primarily detect odors. On each antenna are 72 types of odor receptors and at least 27 are for detecting chemicals in animal perspiration. The head itself is elongated with the familiar proboscis for feeding.

Mosquito fun facts

Their legs and wings are attached to their thorax. Mosquitos have been known to fly continuously for up to 4 hours at 1-2 km.hr (0.6-1 mph) and can travel up to 12km (7.5 miles) in one night. They can beat their wings up to 800 times per second, 4 times faster than other insects of their size, which is why they have such amazing aerodynamic maneuverability in air. The mosquito abdomen is for food digestion and egg development. It should be noted that the mosquito abdomen can hold up to three times its own weight in blood! Mosquitos are crepuscular feeders, meaning they primarily feed during dawn or dusk (they rest during the heat of the day). The bump left on the skin after a mosquito bite is called a wheal. This is due to the inflammation response of histamine release from mast cells in fighting off the introduced mosquito proteins from their bite.

How to locate prey

Mosquitoes use a variety of means to locate prey such as chemical, visual, and heat sensors. A significant part of mosquito sense of smell is designed to smell blood sources. Female mosquitoes seem to prefer type O blood over others (so you scary readers know, yours truly is O+ blood type so I am a prime target for mosquitos). They also prefer those with a lot of skin bacteria, high body heat, and pregnant women. In some respects the attractiveness to mosquitos is a genetically inheritable trait. To find these delicacies the female mosquito detects CO_2, the primary byproduct of blood carrying life forms, as well as the host compound, 1-octen-3-ol, which is present on the skin from sweat (those who sweat have a higher body heat and therefore more ‘octen’) and body odor. Perhaps octen sweat smells better to mosquitos! In particular, the *Aedes aegypti* mosquito has an odor receptor gene that is especially attracted to sulcatone (or

6-methyl-5-hepten-2-one, for those chemists out there), which is predominant in human blood.

Mosquito spit
Just before and while mosquitos enjoy a blood meal they inject a small amount of their saliva. In their saliva is an anticoagulant that helps to keep the female proboscis from being clogged with blood clots. Unfortunately, through this saliva the mosquito can introduce many pathogens into their host; prime examples are, as mentioned, malaria and Zika virus. As a result, mosquito saliva can alter the host immune response.

Proboscis
The female mosquito feeding tube, the proboscis, is very specialized with a sheath surrounding the mandibles and maxillae that actually pierce the skin. The hollow tube that pumps down anticoagulant saliva and draws up blood is called the labrum. Currently, much research is being done with these anticoagulant (anti-clotting) factors since they may be useful in cardiovascular disease.

Misquotes
The proboscis on the 'skeeters' in the film appears to be about 8-10mm (about 3-4 inches) long. It would take a significant force to drive this proboscis into animal muscle and bone, much more than what these mosquitoes could deliver. Furthermore, with such deep penetration not all that much blood could be extracted since the tip of the proboscis would most likely be buried in muscle tissue and not in a blood vessel like their smaller cousins would do. A single "bite" from one of these skeeters would not be enough to kill though no doubt they would hurt! However, multiple bites appears to be life threatening.

MIMIC (1997)
Brief synopsis. A cockroach-derived plague disease, called, "Strickler's Disease", is infecting New York City children. An entomologist, in an attempt to create a cure, inadvertently creates giant killer cockroaches, referred to as 'Judas' cockroaches. These giant cockroaches infest the NYC subway system. These cockroaches mimic a human form and are hybrids of mantids, termites, cockroaches, and humans that are eventually destroyed by fire.

Everyone hates cockroaches, including yours truly. The common cockroach species is *Blattodea*. Much of the under riding theme of this film has to do with insect mimicry. Mimicry is the similarity of one organism to another and can be morphological or behavioral. Mimicry can evolve (or even co-evolve) between different species or between those of the same species. The core of mimicry is to evade predators and can involve appearance, behavior, sound, or scent. When mimicry is an advantage between two species this is called mutualism and when a disadvantage this is then called parasitic or competitive mimicry. Most known mimics are insects.

Mime the mimics

Mimics evolve to share some relatively perceived characteristics with another species, called the models. There are also examples of species that can masquerade as something inanimate such as insects that resemble twigs or leaves. Another example is some species have “eyespots” that may resemble eyes of larger animals and therefore may be more frightening and providing defense. Mimicry has been suggested that it evolved as a positive adaptation. It should also be noted that some mimicry is imperfect since natural selection drives mimicry.

Animal coloration is one of the more obvious examples of visual mimicry. Many species can change coloration for mimicry. Another example is several species of beetle mimic the appearance, odor, and behavior of army ants in order to infiltrate the colony and eat the ants’ young.

Mimic the mimics

There are many types of mimics and the different types are mostly a functional difference. In automimicry one member of a species mimics other members of the same species. Defensive mimics are used to avoid problems by deception so the mimic does not “look” like the enemy. Batesian mimics are the harmless that mimic being harmful. Mullerian mimics are harmful species that advertise themselves as harmful. Mertensian mimics are harmful that resemble less harmful species. Another is Vavilovian mimicry where visual clues are used to resemble other species.

The ol’ two-step

Mimicry evolved as a two-step process. The first step involves gene modification(s) or mutations that cause changes in morphology. The second step involves the selection of the gene(s) that cause small phenotypic changes thereby making the two species more resemble each other. Genetically, single point mutations in DNA (like changing one letter in a sentence) can cause large phenotypic changes whereas many other mutations may make smaller changes. All these mutations contribute to the overall mimic appearance.

In explaining the situation, the entomologist says, “Since [cockroaches] have been proven to be virtually immune to chemical control, we had to find a new avenue of attack. With the aid of genetics labs across the country (then many were in on it!) we recombined termite and mantid DNA to create a biological counter agent, a new species to be our six-legged ally in wiping out the roach population. We call it the Judas breed. Once in contact with the Judas’ secretions, the common roaches were infected with an enzyme that caused their metabolism to go into overdrive. No matter how much the common roaches ate, every last member of their nest starved to death in a matter of hours…the transfer of recombinant genetic material from termites and mantids into Judas breed will allow rapid enzymatic change…showing 100 percent sterility in all

Judas females." Later, the entomologist goes on to say, "Sometimes an insect will evolve to mimic its predator. A fly can look like a spider, a caterpillar can look like a snake. The Judas evolved to mimic its predator…us."

Late in the film we finally get to see an adult Judas insect that appears to be about six feet tall and 'wearing' what looks like an overcoat. After looking at a freshly killed adult Judas a physician comments, "These are lungs. Biology 101. Insects don't have lungs. Its what limits their size." These cockroach mimics solved the respiration problem that limits insect size by developing animal lungs for respiration that, in turn, would not limit their size.

Conclusions

Based on these films, small insects can mutate to giants, swarms can have an organized attack, humans can turn into insects, and insects can turn into humans. There are four types of mutations in the films discussed here. Accidental mutations caused by radiation (Them!, The Beginning of the End), toxic mutations (Skeeter), purposeful mutations (The Fly, Wasp Woman, Mimic), and natural mutations (The Deadly Mantis, The Deadly Bees). Of the many insect films, including those discussed here, it is the bee films that, to me, are the least scary. Though swarms can certainly be deadly they do seem somewhat easy to deal with. Bees are too much of a friend to mankind whereas the other insects not so. If we ignore the physically limiting scaling issues then bug films seemingly do make sense. And, to be sure, whether they make sense or not, bug films are fun to watch. Bugs are everywhere and are an inescapable part of life. Man has learned to be in harmony with insects and though some can kill most are our friends. Scary indeed!

Thank you for reading. It's back to the lab for me. Stay healthy and eat right.