

The Five Stages

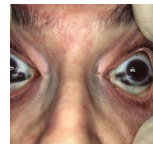
Important to keep in mind: The stages are a framework not a rule.



Fresh

- Breakdown starts as soon as heart stops
 - Cell walls lose integrity, releasing enzymes to process tissue in the body
 - Bacteria breaks down intestinal - **Autolysis**
 - Autolysis causes blisters (13)
- **Mortis Triad**
 - Pallor Mortis (honorary addition)
 - The skin becomes pale after death
 - Color change affects:
 - Nail beds, lips, gums, tongue, and skin
 - Does melanin matter?
 - Myth: This only occurs with white skin
 - Fact: Happens to all bodies, but the way it manifests differs (26)
 - Pallor mortis is different than low levels of melanin
 - Caused by loss of circulation of oxygen-rich hemoglobin
 - There *is* skin color difference among sexes, but that disappears post-mortem with Pallor Mortis(27)
 - Happens very quickly, within less than half an hour
 - Because of the speed at which it happens, it's useless in determining time of death
 - Considered "first stage" of death (according to one source, so take that with a grain of salt) (23)
 - Rigor Mortis
 - ATP (Adenosine Triphosphate) is converted to ADP (Adenosine Diphosphate) and lactic acid is produced, lowering the cells pH and making the body go rigid
 - Onset begins 2-6 hrs after death in the face
 - Lower temperatures accelerate onset and extends the length of rigor mortis
 - Opposite is found in higher temperatures
 - If the individual was very active before death, then the onset happens quicker
 - All the muscles in body are affected 4-6 hrs after death
 - Rigor mortis starts with muscles in the face and makes its way through the rest of the body (30)
 - Peaks at 12 hr, gone by 48 hr
 - **Cadaver spasm**
 - Premature stiffening of corpse before Rigor Mortos

- Body may twitch or spasm
 - **Algor Mortis**
 - Body temperature cools to room temperature in around 18-20 hrs (30)
 - Generally calculated using this equation
 - $PMI(h) = [98.6 - \text{Body temperature}(F)]/1.5$
 - This technique shouldn't be used if body was there for 18 hrs or more and isn't accurate as there are a variety of factors
 - Factors include body mass, exposure to sunlight, clothing and more (30)
 - Closer body is to room temperature = the longer it's been dead
 - **Liver Mortis**
 - Gravity-dependant accumulation of blood in skin that created purple-red discoloration (6)
 - Liver Mortis is also referred to as lividity, post-mortem hypostasis, vibices, and suggilations
 - Often seen around one hour after death and fully develops after 2 - 4 hours (30)
 - Infestation and Buildup
 - Lack of O₂ creates stellar living space for anaerobic organisms
 - **Anaerobic organisms** - An organism that does not require oxygen (21)
 - **Facultative anaerobes**
 - Can live with and without oxygen
 - Human cells are typically facultative anaerobes
 - Example: Muscle cells during exercise will switch to lactic acid
 - **Obligate anaerobes**
 - Cannot survive in oxygen
 - Consumes carbohydrates, lipids, and proteins
 - Chemical release attracts flies and other insects
 - Blowflies lay eggs in openings (mouth, nose, etc)
 - Look
 - Skin
 - Purple red/ Blue purple discoloration
 - Skin also goes yellow
 - Skin cracking
 - Eyes
 - Eyes cloud over and are often crossed slightly
 - Tache Noir (30)
 - Eyes may remain open and the cornea will dry up
 - Leads to red-orange to black discoloration of the eyes
 - Symmetrical distribution
 - Distribution relies on position of the eyelids
 - Mouth stretched and slightly agape



- Chemical changes
 - Increase in atmosphere
 - CO₂, methane, hydrogen sulfide, nitrogen, ammonia
 - Increase in grave soil
 - Ammonium, nitrate, phosphorus, soil pH (2)

Bloat

- Gasses
 - Anaerobic metabolism leads to accumulation of gasses (hydrogen, sulfide, CO₂, methane, etc) (2)
 - Causes an increase in temperature above the ambient temperature
 - Body becomes its own habitat in a sense (30)
 - Causes distention of abdomen and gives body a “bloated” appearance
 - Buildup of gasses may cause it to rupture
 - Allows O₂ to re-enter the body
 - Helps develop fly larvae and aerobic microorganisms
 - Putrescine and Cadaverine (24)
 - Putrescine
 - Formed through decarboxylation of ornithine and arginine
 - Cadaverine (25)
 - Formed through decarboxylation of lysine
 - In low concentration, smells like semen
 - Is actually found in semen
 - Putrescine and cadaverine are chemically identical
 - Causes strong stench of decay
- Fluids
 - Gas causes natural liquids to froth
 - Fluids forced to escape through mouth, nose, anus, ears, etc
 - Blood leaks from mouth and nose
- Infestation
 - Maggots hatch from fly eggs and feed on tissue
 - Maggot activity causes skin to slip and hair to detach
 - Ruptures create new openings for flies
- Look
 - Body turns from greenish yellow to red as blood decomposes
 - Skin can turn green and black in this stage (there are contradictory opinions)
 - Skin slippage (30)
 - The skin as an organism is dead and in moist environments the epidermis (top layer of skin) separates from the dermis (middle layer of skin) as hydrolytic enzymes are produced in between the layers



Glove → formation

- Chemical changes
 - Increased in grave soil
 - Ammonium, calcium, chloride, fatty acids, magnesium, organic N, phosphorus, potassium, nitrate, sodium, sulfate
- HEAVY OVERLAP WITH ACTIVE DECAY

Active Decay

- Mass is lost
 - Result of maggot feeding and purging decomposition fluids
 - Very strong odor as tissue further deteriorates
 - Purging of fluids marks beginning of this stage
- Cadaver Decomposition Island (CDI)
 - Purged fluids accumulate around body
 - Purge fluids
 - Decomposition fluids that often exudes from oral and nasal cavities
 - Commonly misinterpreted as antemortum hemorrhage
 - Decomposition fluids in chest cavities
 - Low volumes of red-brown fluid mimic hemothoraces
- Insects
 - Stage most insects are present
 - Maggot activity peaks
 - The size of maggots can be used to give a measurement of minimum time since death
- Look
 - Exposure of internal organs
 - Increased marbling
 - Color change of blood vessels
 - Can resemble plant roots or branches
 - Can be in same location as livor mortis
 - Slippage of skin
 - Time frame according to some sources:
 - Several weeks
 - Nails/teeth fall out
 - 1 month
 - Body liquifies
 - 3-4 months
 - Complexion turns brownish red
- Biological Changes
 - Death of associated vegetation (unsure why)



- Elevated microbial activity
- Shift in bacterial community structure
- Chemical Changes
 - Some elevated concentrations as bloated
 - Increased
 - Lipid phosphorus
 - Enzyme activity
 - Protease activity
 - Phosphodiesterase activity
 - Total nitrogen
 - Total phosphorus

Advanced Decay

- Decomposition
 - Loss of cadaver material leads to decomposition being inhibited
 - When body cohesion breaks down, bones sometimes fall away and scatter
 - Adipocere
 - Corpse wax may form, further slowing decomposition
 - Putrefaction (6)
 - Process in which tissues and cells break down and liquidize as the body decays
 - A decomposing human body will eventually release 32g of nitrogen, 10g of phosphorus, 4g of potassium, and 1g of magnesium for every kilogram of *dry* body mass
 - Result of all combined activity from organisms
 - Makes changes in soil that will last years
- Environment
 - If in soil, surroundings show evidence of vegetative death that can last years
- Biological changes
 - Maggots have migrated
 - Corpse comprises of skin, organs, hair, and bones
 - Declining microbial biomass and activity but still greater than non-gravesoil
 - Fruiting of Post Putrefaction fungi
 - Shift in bacterial community structure
- Chemical Changes
 - Same as bloated and active decay



Dry/Remains/Skeletonization

- Remains
 - Dry skin, cartilage, and bones
 - Bones become soft and bleached if exposed to the elements

- If all soft tissue is gone, it's completely skeletonized
 - Once bloating ceases, the soft tissue that might remain collapses in on itself, eventually drying out, and beginning to skeletonize
- Are bones guaranteed to become fossils?
 - No, in fact, bones are often recycled in nature through a process known as Bone Weathering (28)
 - Bone weathering
 - Stages
 - **0** - Bone surface shows no cracks or flaking
 - Greasy
 - **1** - Bone starts to crack (parallel to fiber structures)
 - Tissue might still be present during this stage
 - **2** - Outermost layer of bone starts to flake off in long thin flakes.
 - Flaking continues until most of the outer bone has flaked off.
 - Tissue might also still be present
 - **3** - Bone is covered in rough, weathered compact bone patches with fibrous texture.
 - It spreads till bone loses the current layer, revealing only the weathered compact bone layer.
 - Does not penetrate deeper than 1.1 - 1.5 mm at this stage. Bone fibers are still attached.
 - Tissue rarely present during this stage
 - **4** - Bone surface is rough with fibrous texture and splinters start to form.
 - Splinters may become loose enough to fall off the bone.
 - The inner cavities are penetrated at this stage.
 - **5** - Bone falls apart and is very fragile
 - Large splinters lay around what is left
 - Original bone shape is near impossible to decipher
- Environment
 - Resurgence of plant growth around CDI

Decomposition Extraneous

- **Major factors**
 - Natural from 1-5 (5 being greatest affect, 1 being the least)
 - Temperature - 5
 - Colder = slower
 - Cold delays onset of autolysis (14)



- Insect activity is affected by cold as well
 - Below 6 degrees celsius, most insect activity doesn't happen
 - In high, dry temperatures, insect activity also doesn't happen
 - Mummification will usually happen in that circumstance (30)
 - Moisture - 4
 - Rainfall - 3
 - Access for bugs - 5
 - Wind speeds past 16 km/h ceases insect activity
 - NOT a consistent rule
 - In tropical settings, wind speeds exceed this and there's still a lot of insect activity (30)
 - Access for animals - 4
 - Injuries - 4
 - Body size and weight - 3
 - Embalming - 3
 - Clothing - 2 (2)
 - Post Mortem classifications
 - Putrefaction (22)
 - Process of decay/rotting in a body
 - Putrefaction is also used to refer to the foul smell of cadaver decay
 - Considered *fifth* stage of death in reference to the mortis triad and pallor mortis
 - Mummification
 - Process of preserving a body by drying or embalming flesh
 - Removes moisture using chemicals or natural preservatives (i.e. resin) (6)
 - Removes organs to avoid moisture from within (15)
 - Adipocere
 - A grayish wax formed by decomposition of soft tissue in bodies subjected to moisture
 - Allows face shape, injuries, etc, to be well preserved
 - Maceration
 - Softening and breaking down of skin resulting from prolonged exposure to moisture (think of putting printer paper in a bowl of water) (6)
- Burial
 - How does burial affect the rate of decomposition?
 - Slows rate of decomposition as few inches of soil keep blowflies from laying eggs on the corpse

- Depth, type of soil, moisture level, temperature, all affect decay
- Time
 - The first month has the most drastic change
 - After a month, the difference is less stark
 - The body is essentially liquified
 - After ten years, there's only teeth and some bones left (15)
- What some are buried in:
 - Casket
 - The casket "pressure cooks" the body, turning it into more a chunky stew than a typical cadaver
 - Sometimes the pressure is high enough that the casket bursts open.(14)
 - Decay happens faster in a wooden casket, rather than a metal one (15)
 - Difference between casket and coffin
 - Caskets have four sides
 - The lid is hinged
 - Coffins have six sides and the top is wider than the bottom
 - The lid is easily removed (17)

Autopsy stitches



trocar



- Autopsy techs
 - Examines the cadaver and may analyze or even remove organs (15)
- Embalming
 - Undoes stitches from autopsy (15)
 - Only takes place when body was autopsied
 - Drains the organs of fluids with a **trocar** (16)
 - Only takes place when body was not autopsied
 - Injects the bodies with embalming fluids (preservation chemicals) (15)

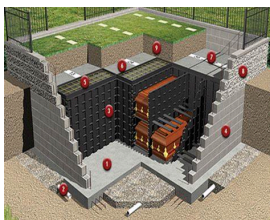
trocar buttons



- Injections are made through the torso and are sealed using plastic caps called a **trocar button**
- Delays decomposition for extended time
 - The vagina and anus may be sealed with cotton to avoid any leakage from the fluids (16)
- Insecticides (30)
 - Insecticides delay insect activity
 - Does not permanently delay insect activity
 - Immature insects can still nest, even with high concentration of insecticides that would normally kill an adult of the same species

- Mortician
 - Morticians dress and use make-up on the corpse to make it seem more alive (18)
- Types of Burial
 - How to identify different burials
 - Number of Dead:
 - Single
 - Secondary deposition (multiple single graves)
 - Ossuary
 - Container where a body/bones are placed
 - Like jars
 - Double
 - “Companion space”
 - Typically includes married couples, as well as close friends and family
 - Cost effective
 - Multi
 - Collective burials
 - Plagues
 - Cenotaph (No bodies) (Fake Grave)
 - Memorials for someone buried elsewhere
 - Think graves for soldiers never found
 - Burial Depot
 - Mortuary
 - Burials inform us in two ways
 - Which divides up between bio/physical anthropology
 - What people were like in life
 - Sex identification in anthropology is highly debated and unreliable at times
 - How they were treated by the living
 - The dead don’t bury themselves (duh)
 - Contemporary Types of Burials (19)
 - In-ground burial
 - Typically involves a casket/coffin being buried six feet beneath the earth
 - Often includes flat, upright headstones
 - Above-ground burial

Lawn Crypt Set-up



- Lawn Crypts (20)
 - Underground vaults made of reinforced concrete and steel to store caskets of loved ones
 - Keeps caskets “clean” and “dry”
 - Obviously not dry inside cause that shit’s gonna cook

- Can hold six to twelve caskets

- **Mausoleums**

- Similar to lawn crypts and are usually stone buildings above ground to store caskets
 - Popular in places where in-ground burial is inaccessible
- Historical significance
 - Used for thousands of years
 - Pyramids are an example of mausoleums



Industrial furnace



- Cremation
 - One of the most popular contemporary burials
 - Involves burning the body in temperatures between 1,400 - 1,800 degrees fahrenheit
 - People often scatter the ashes of their loved ones
 - People often put the ashes of their loved one in an urn
 - **Urn** - a sealed vase used to store human remains in the form of ashes



Natural burial



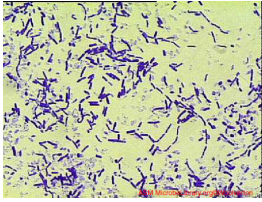
- Natural Burial
 - Involve burial without any embalming fluid, casket, etc
 - Entirely natural, hence the name
 - Human Corpse
 - A high quality resource
 - An ephemeral resource patch/disturbance
 - A source of water
 - A habitat for microorganisms (2)
- **Body Farms**
 - What are body farms?
 - A few acres of land where donated bodies are placed in order to study their decomposition in various settings
 - The birth of the body farm
 - William M. Bass, University of Tennessee, Knoxville - 1972
 - Conceived of idea as an anthropologist interested in the process of human decomposition, which was not studied in depth with actual human cadavers

- Facilities Across the U.S.A
 - University of Tennessee Anthropological Research Facility
 - Located on Alcoa Highway, Knoxville, Tennessee
 - The first body farm made by William M. Bass
 - Originally consisted of 2.6 acres and is on a wooded plot surrounded by razor wire fence
 - ~100 bodies donated per year
 - Western Carolina University/ Forensic Osteology Research Station (FOREST)
 - Opened in 2006 by WCU's forensic program
 - Studies decomposition in mountainous habitats
 - FOREST has been used for cadaver dog training (aw!)
 - Forensic Anthropology Center at Texas State (FACTS)
 - Opened in 2008 by TSU San Marcos department of anthropology
 - Under direction of Dr. Michelle Hamilton
 - Former student of William M. Bass
 - Southeast Texas Applied Forensic Science Facility (STAFS)
 - Opened in 1976 in Sam Houston State University
 - 247-acres of land for cadavers
 - Buildings are morgues with freezers and cooler units
 - Complex of Forensic Anthropology Research (CFAR)
 - Opened Oct, 2010 in Southern Illinois University
 - Useful as temperature is much lower in Illinois as opposed to the other body farms
 - Winds are also higher in Illinois, adding another factor
 - They use pigs instead of people
 - First human donated in January, 2012
 - Forensic Investigation Research Station (FIRS)
 - Opened in 2012 in Colorado Mesa University
 - First pig - Sep, 2012
 - First human - Nov, 2013
 - As of Jan 18, they've had a total of 11 humans
 - Most arid body farm currently available + highest altitude
 - OFS Facility for Outdoor Research and Training (FORT)
 - Opened in Sep 19, 2018 in Tampa Florida
 - Only subtropical body farm
 - 3.4 acres
 - Started with five cadavers
 - The site lost its contract to a vote in May, 2019. It was shut down May 7, 2022
 - Currently trying to find a possible alternative site
- Taxonomy
 - What is doing the decomposing?

- Most decomposition is biologically mediated (Minimum 80%) (2)

- Micro-organisms

- Bacteria



- Decomposer bacteria plays a big role, especially in the beginning, when moisture levels are high

- Examples

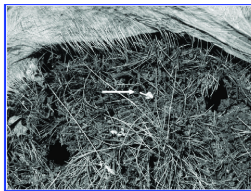
- Bacillus Subtilis, Pseudomonas Fluorescens

- Later stages fungi tends to dominate

- [Fungi](#)

- Post Putrefaction fungi

- Taphonomic Mycota
 - Field mycology provides further tool towards investigating bodies concealed in forest ecosystems
 - Fruiting structures of certain fungi; ammonia and post putrefaction fungi are in association with decomposed mammals



- Ammonia fungi

- Death loving fungi are known for producing their mushrooms in forest soils enriched with ammonia and other nitrogen containing compounds such as urea and amino acids
 - Nitrogen is a big deal as its difficult to find naturally outside of dead bodies

- Arthropods greatly vary depending on habitat and there are four basic arthropod/cadaver relations

- Necrophagous species - Directly feeds on corpse

- Flies (blow flies and flesh flies)

- Early arrivals
 - Fly larvae (maggots) are most abundant. Muscidae and blowflies are first to arrive and lay eggs
 - The larvae and parents feed on the body fluids and enter body through openings
 - Different species of horsefly and blowflies arrive at different times



- When corpse dries out, Piophilidae and Phoridae clean up skeleton
- Larvae feeds larger animals
- Beetles (The Beatles metal band counterpart)
 - The beetles first arrive as soon as the body begins to putrefy
 - The beetles have chewing mouthparts (mandibles) and can therefore eat through the skin more easily, mostly the tougher parts of the tendons, etc
 - Three types of beetles benefit from the corpse
 - Early arrivals
 - They are predatory adults that eat the fly larvae and might lay their eggs in the cadaver as well
 - i.e rove beetles and hister beetles
 - The beetle larvae
 - Also having powerful jaws, they further feast on the fly larvae (and I'm assuming carcass)
 - Late arrivals
 - These are the specialist scavengers, which feed on tougher parts like skin and tendons as the body dries out.
 - Most late stage scavengers include the larvae of hide beetles and ham beetles
 - Carrion beetles are more easy-going and are able to generally eat most corpses, although the larvae must settle for moist corpses (gross)
 - Many dung beetles are attracted to large carcasses
- Mites
 - Feed on corpse throughout the stages
 - Regardless of exposure to elements



Maryland Carrion Beetle

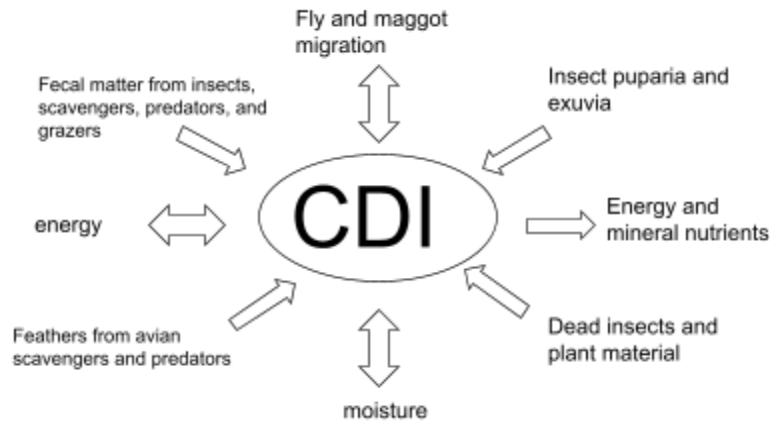


- The mites and beetles have an alliance going on where the mites keep the maggot population low to allow the beetles space to occupy the carcass
 - Moths
 - Feeds on hair
 - Lay eggs in carcasses after fly larvae are done
 - They are therefore the last animals contributing to the decomposition cycle (11)
 - Predators and parasites of necrophagous species
 - Beetles
 - Silphidae
 - Staphylinidae
 - Histeridae
 - Flies
 - Calliphoridae
 - Stratiomyidae
 - Wasps
 - Hymenoptera
 - Many beetles and true flies don't feed on the corpse, but the insects surrounding it
 - Feed on fly larvae
 - Parasitic
 - Some of the insects that are necrophagous pupae grow up to become predators to necrophagous species
 - Omnivorous species
 - Species that feed on both the cadaver and the necrophagous species
 - Wasps
 - Ants
 - Some beetles
 - Large swaths of these slow decomposition rate by depleting necrophagous species
 - Adventive species
 - Species that use the corpse as a home
 - Springtails
 - Spiders
 - Centipedes
 - Millipedes
- Scavengers
 - Nocturnal mammals

- Racoons
 - Small rodents
 - Opposum
 - Carrion birds
 - Vultures
 - Corvids
- The Difference between scavengers and decomposers
 - The difference between scavengers and decomposers is that scavengers break apart the dead into smaller pieces and the decomposers FURTHER break-down said material
 - Think of scavengers as a sort of prelude to decomposers, even though they exist in similar time frames
 - Both are within the third trophic food web

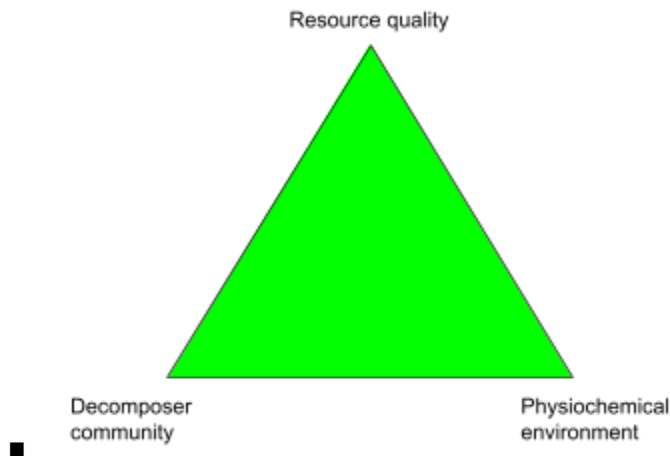
Category	Scavengers	Decomposers
Definition	Organisms that feed on cadaver	Organisms that break down the cadaver's organic matter into its simplest form to be absorbed into the soil
Kingdom(s)	Animal kingdom	Fungi, monera, and animal kingdom
Other names:	Detritivores	Saprotrophs*
Role	Break down the cadaver into smaller pieces	Break down the smaller pieces into tiny particles
Examples	Insects, worms, birds, and crabs	Bacteria, fungi, and earthworms

- (12)
 - *Saprotrophs - Chemoheterotrophic extracellular digestion of decaying matter
 - More often than not associated with fungi
 - Chemoheterotroph - An organism that gets its energy from chemicals and needs to consume other organisms in order to live
 - Example: Mammals



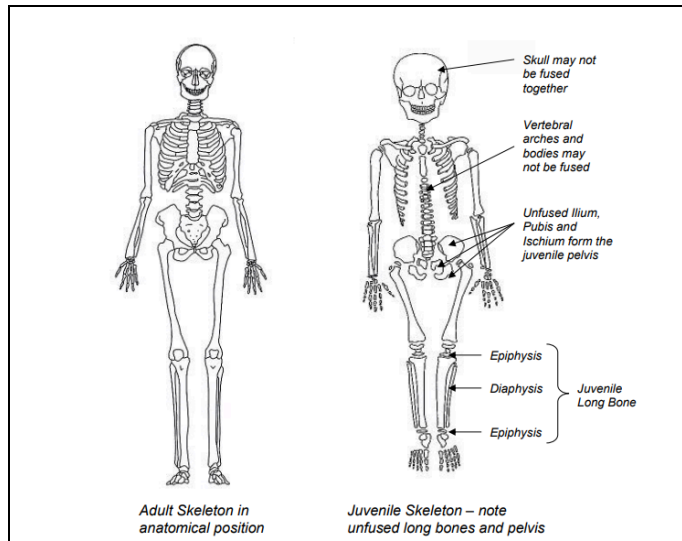
- **Taphonomy**

- What processes are taking place?
 - Catalysis
 - Enzymatic and chemical reactions transforming complex to simple
 - Comminution
 - Physical breakdown of resource
 - Leaching
 - Soluble material moved by water
- Regulation of Decomposition



- **Forensic Anthropology/ How Human Decomposition is Studied and Why**

- Excavation of human remains (29)
 - The benefit
 - Study the diseases of the past
 - Dietary practices
 - Understood through study of human remains teeth
 - Understand the demographic changes over time
 - Bone structure and discrepancies in sex
 - Age and Sex in human remains
 - Depends on ability to recover well-preserved skulls and pelvises

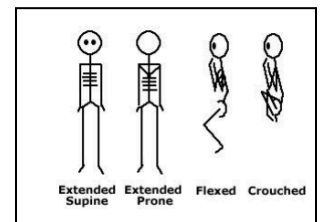


- These areas have the most present sexual dimorphism
 - Keep in mind, not always accurate. Prehistoric bones were often misidentified as male because the typical bone structure of females differed from now
- Pelvis
 - The auricular surface where the pelvis meets the sacrum at the bottom of the spine can be used to measure age
- Teeth
 - Wear of tooth surface can be used to measure age
- Long bones
 - Crucial in identifying age in juveniles
 - Long bones must be recovered in one piece
 - Long bones are also used to measure stature in adults

■ Understanding burial practices of the past

● Different postures of the dead

- Extended Supine
 - Straight and on their back
- Extended Prone
 - Straight and on their stomach
- Flexed
 - Slightly curled to the side
- Crouched
 - Very curled to the side



● Posture differs In war

- Hands clasped together (like in Kenya)
- No specific orientation
- Mass graves

● Importance of location in human remains

- Bones aren't always found where expected
 - Some burials have heads removed or found between toes
- Carefully chart location of the bones
 - Helps with differentiating human remains from animal remains

- Remains could be intermingled with other humans remains
 - Remains could have been removed and put back for ritual purposes
 - Urban cadavers
 - Burial
 - Bodies typically buried in deeper graves
 - Typically part of complex stratigraphic locations
 - Concentrated around specific sites
 - Example: churches
 - Cons
 - High chance of bones being damaged by other features, including later graves
- Preservation
 - Importance of soil
 - Some burials in soil may leave no trace at all
 - Body can still be studied as there could still be an outline of the body in the dirt in the form of a dark stain
 - The body stain is key in differentiating it from a cenotaph
 - Perfect dirt for preservation of bodies
 - Alkaline, free draining soil with little post-depositional activity
 - Sands and boulder clay
 - They are very acidic and may dissolve the bones entirely
 - Silt
 - What is silt?
 - Detritus (a.k.a fragments of weathered rocks)
 - Properties similar to sand and clay
 - If grave burial cuts through silt and the grave was backfilled with the natural and then silt on top:
 - The natural would be redeposited on the bottom of the grave
 - The integrity of the grave, hydrolysis, and animal activity are also big factors
 - Burial significance
 - Crypt burial preservation
 - Lead and solid wood coffins
 - May preserve soft tissue
 - Example: hair, nails, and skin
 - Must be treated carefully for health reasons
 - Prehistoric Barrow
 - Prehistoric barrows are mounds of earth over one or more prehistoric grave

■ Excavation of bodies

- Don't excavate soil from with the eye orbits, the nasal aperture, the auditory meatus, the mandible, and any holes that may have occurred
 - Eye sockets contain very delicate bones
 - Soil from the mandible shouldn't be removed because there are often bits of bone and possibly cartilage in the area and are easy to miss

■ Bones to be found in the jaw area

● Hyoid bone

- Present in everyone and present in jaw area near the throat

● Thyroid Cartilage

- Present only in some people
- Very fragile

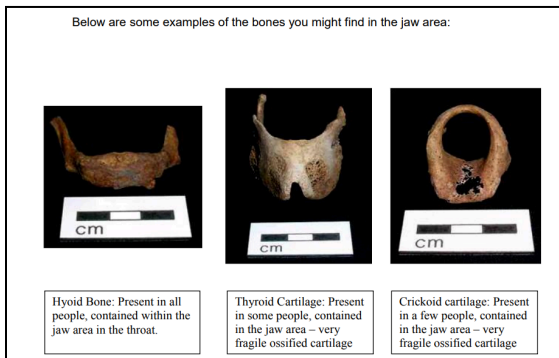
● Crickoid Cartilage

- Present in very few people
- Very fragile

- The ear contains three very delicate bones

● Order of excavation

- Skull to neck to torso to arms and legs to hands and feet



SOURCES

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