Evolutionary considerations of venoms and toxins

ALL STINGS CONSIDERED

Goals

- Provide context to understand toxins and venoms.
- Discuss benefits and costs of toxins
- Understand when anti-toxins will be useful
- Find clinical application of these concepts
- First: what is the difference between a venom and a toxin?

Medical definition of venom & toxin

- Toxin: any substance that is harmful to humans
- Venom: a toxin that has a delivery apparatus
- Venom has a function that benefits its bearer

Toxin

- This is a grab bag term:
- Pharmaceuticals are toxic at high doses
- Many inorganic substances are toxic
- Benzene, Dioxin
- Asbestos, Arsenic
- Lead, Nanoparticles
- Radioactive materials
- Water intoxication
- Oxygen toxicity

Venom

- Complicated delivery apparatus and metabolically expensive venom
- Complex functional physiology
- Benefits organism in obtaining food or providing protection from predators.

Nematocysts

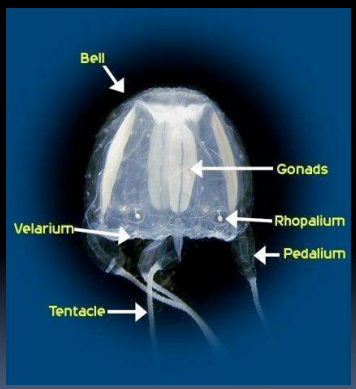
Cnidaria

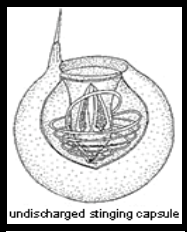
True Jellies

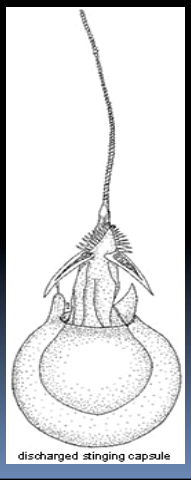
Physalia

Fire coral

Anemones



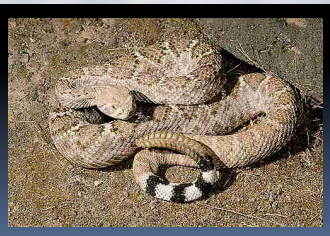




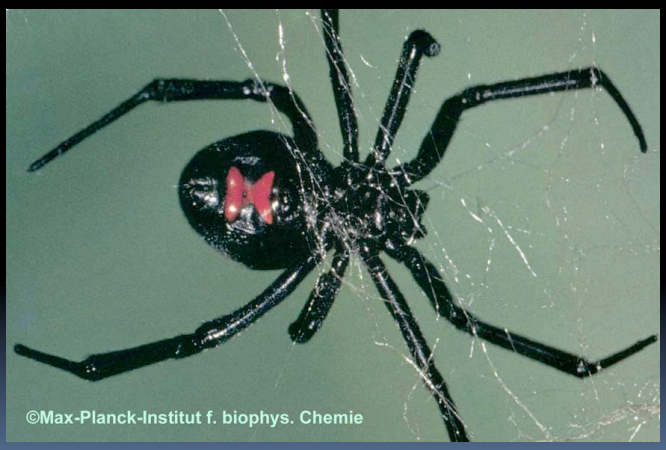
VENOMS

Rattlesnake Bites

- Male > Female
- Stupid Risky Behaviors
- Some are inadvertent
- Dry



Latrodectus



- *Fatalities in California, Columbia, Fiji, New Zealand, Surinam, Australia & Texas.*


ZF

- *3 deaths in Australia with barb penetrating heart!*
- *For more minor lacerations – immerse in hot water*

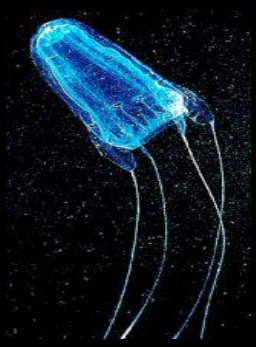
Blue Ringed Octopus

- Venom injected with salivary glands,
- Tetrodotoxin
- Within minutes victim develops numbness of lips and tongue
- Severe envenomations proceed to weakness and respiratory failure

Why is octopus bite toxic?

- What is the function of the toxin?
- Are humans the intended target?

Box Jellyfish

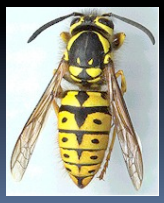


Only the tentacles can deliver envenomation

Chironex fleckeri sting

Insects

- Most deaths as a result of a bite or sting involve insects! (dogs are number two)
- Hymenoptera - Honeybees, Yellowjackets, and Fire Ants.
- Venom components
- Deaths usually because of allergy



Las Cruces Park Closed Following Discovery of Red Imported Fire Ants

- Feb 2005
- Red Imported Fire Ants within the City park along the banks of the Rio Grande.

Venom Function

- Combined predation/defense
  - Active predation – rattlesnakes, black widow spider
  - Passive predation – jellyfish, fire coral
- Defense only – stonefish, lionfish, honeybee, stingray, harvester ant

ACTIVE PREDATION

- Rattlesnakes eat vertebrate prey
- Some wasps compete with vertebrates for prey. E.g. yellowjackets on your ham sandwich
- Both venoms are active against vertebrates – thus people too.
- Snakes often withhold venom
- Spiders and Yellowjackets deliver variable quantities of venom

PASSIVE PREDATION

- JELLYFISH DO NOT WITHHOLD VENOM – LACK ABILITY TO DISCRIMINATE BETWEEN PREY AND NON-PREY

Defense only venoms

- No predatory role. Generally prevent organism from getting eaten or prevent relatives from getting eaten.
- Stingrays
- Stonefish
- Honeybees
- Harvester Ants

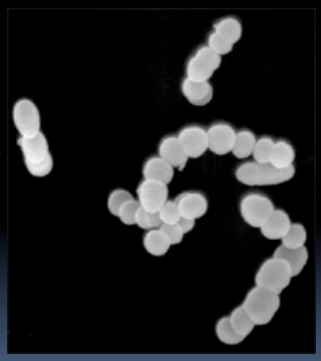
(honeybees & harvester ants use venom to fend off vertebrate predators)

Biologic Toxin

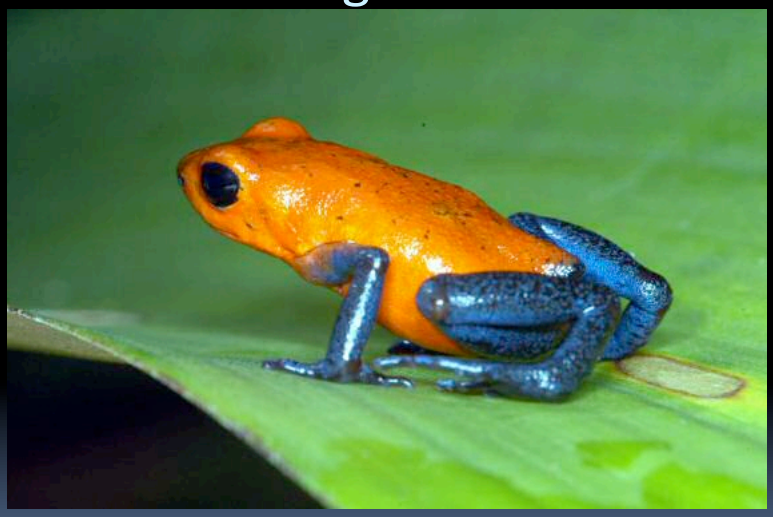
- Product of an organism that can harm other organisms
- Medically relevant subset – product that has capacity to harm humans
- Evolutionary context: biologic activity of the substance helps the organism reproduce and pass on its genes

Enterotoxigenic E. Coli

Streptococcus perforins



Back to biologic toxins



Fugu

- Toxic Pufferfish
- Known in sushi bars as Fugu
- Prepared by specially trained chefs in Japan.
- Several tens of cases each year in Japan
- Mortality exceeds 50%!

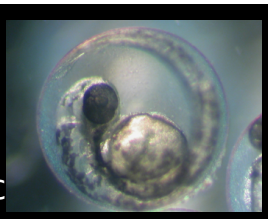
Fugu/Tetrodotoxin poisoning

- Most powerful emetic known
- Severe GI upset with profound vomiting, pain.
- Also paresthesias, ataxia, respiratory depression.
- Victims proceed to coma, convulsions, and death within hours

Pufferfish

- Why is it toxic?

Pufferfish



- Adult toxicity byproduct of selec
  poisonous eggs?
- Females more toxic than males
- Eggs and larvae contain TTX
- Eggs and larvae are unpalatable to predators
- If one egg gets eaten and makes predator sick – rest of eggs (carrying copies of same genes) likely to survive.
- Humans have died from eating eggs.

If you survive the Fugu and like to live dangerously

- You might partake of a barbequed giant barracuda

Off Freeport Texas,

- Several crew members falls ill with nausea, weakness, and paresthesias
- Some report mouth numbness
- And curious sensation that cold water feels hot…
- All on board had eaten giant barracuda

Ciguatera

Ciguatoxin from dinoflagellate protozoan – Gambierdiscus toxicus

Reef fish concentrate toxin in flesh

Can't cook the toxin out

Venoms with antivenin available

- Rattlesnake
- Black widow spider
- Funnel web spider
- Blue ringed octopus
- Box jellyfish
- Stonefish
- Sea snakes, coral snakes

Pathogen toxins

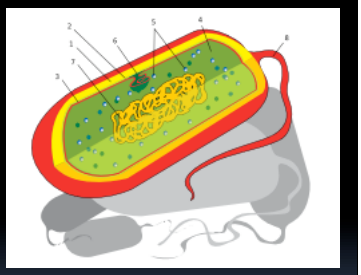
- Diphtheria toxin
- Pertussis toxin (secreted by bacterium
- Tetanus toxin
- Enterotoxigenic E. Coli

Pathogen anti-toxin vaccines

- Vaccines against toxins can act by selecting for strains that are less virulent
- Vaccines eliminate certain strains and give advantages to other, less dangerous, strains
- If we are affecting evolution of pathogens, better make sure we target the right toxins…

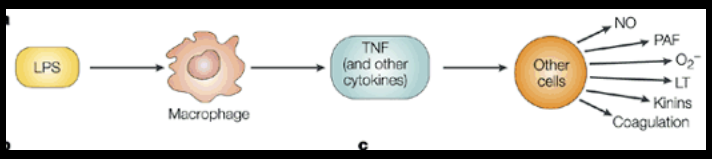
Exotoxins and Endotoxin

- Bacterial exotoxins (secreted) thwart the immune system



- Endotoxin is different
- AKA Lipopolysaccharide
- cell wall of many bacteria
- Not a secreted product – bacteria would prefer to not liberate their endotoxin.

Endotoxin



- Real bacterial toxins do benefit from antibodies and immunotherapy
- If endotoxin is a harmful "toxin" - antibodies to endotoxin should promote health.
- In fact endotoxin resembles a hormone or signal for the immune system

Venom Summary:

- Name of the game is to eat and prevent being eaten
- Dry bites – active predation
- Venoms – severe if directed toward vertebrate prey
- Often accompanied by warnings - elicit avoidance behavior

Toxin summary

- Generally defensive
- Discourage predation or consumption of reproductive unit
- Pathogens express toxins that injure the host and free resources for reproduction (host cells, nutrients and tissues).

Treatment

- Immune therapy exists for many venoms
- Vaccine therapy prevents infection with toxin producing bacteria
- If toxins are misidentified, immune therapy will be harmful!
- Evolutionary view could have predicted this!