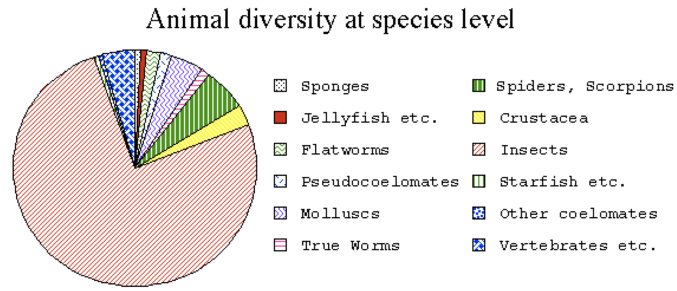
EXOSKELETONS: THE SECRET TO INSECT SUCCESS

Butterflies, ants, lobsters, hermit crabs, spiders, and beetles are all creatures whose way of life is determined and made possible by their exoskeletal body plan. The exoskeleton signifies membership in the Phylum, Arthropoda (derived from words meaning 'joint' and 'foot'). Many members of Arthropoda, such as the sea spiders and crustaceans, live underwater in the oceans and waterways of the world. However insects, myriapods, arachnids, and a few crustaceans are the only animals with exoskeletons which live on land. The unique and resilient exoskeleton enables insects to live in places and do thing that other creatures cannot. Consequently, insects have infiltrated the land with huge, diverse populations. This feat is evidenced by fact that insects comprise approximately 75% of all animal species!



COMPOSITION:

The exoskeleton of insects is primarily made of proteins (sclerotin) and chitin (polysaccharide molecules), which are interwoven and linked together to form strong but flexible bundles. The ratio of the components varies from body part to body part on an insect. This allows for a strong, secure cover where the insect needs secure form and protection such as in the head capsule. At the same time, a different ratio of this composition allows flexibility and protection in places such as the stomach, where the insect needs to expand to accommodate the intake of food or at the joints where the insect requires bending flexibility for movement.

GROWTH:

THE MOLTING PROCESS:

The exoskeleton encases the entire insect. The eyes are even covered by a thin layer of exoskeleton as are parts of the lining of the digestive and excretory pathways. As a non-living formation, the exoskeleton does not change size and grow with the insect. As a result, it is necessary for the insect to shed its old exoskeleton to make way for a new larger one through a process called molting.

As the insect grows and the need to molt arises, hormones are released in the insect's body which signal the process to begin. There are two major layers of the exoskeleton. The outer layer is more ridged while the inner layer is more elastic. The inner layer is broken down and the nutrients reabsorbed for recycling into the new layer. The upper layer remains in place because it is too ridged to be recycled and also it must protect the insect until the new exoskeleton is ready.

A stick insect emerging from an old exoskeleton

Then the new exoskeleton is secreted so that it is positioned in the space the old exoskeleton and the living cells of the insect. The soft new exoskeleton is wrinkled up and already bigger that the old exoskeleton. It is ready for expansion once the old exoskeleton is shed.

The insect expands its body by in taking water or air (depending largely on whether they live in an aquatic or terrestrial environment), or by using concentrated pressure of its blood. This expansion cracks the exoskeleton typically along the back of the thorax of insects. Insects slide themselves out through this division.

Once freed of the old exoskeleton, the soft insect intakes more water or air to puff itself up to be larger than its previous size to allow for growth. With the insect in this expanded state, the new exoskeleton begins to harden. Once the exoskeleton is hardened to the intended level, the molting process is complete!

A bug almost done emerging from it's old exoskeleton

MOLTING DANGERS:

While molting serves as an essential role for insect growth and transformation, it is also potentially the most dangerous part of an insect's life. Approximately 85% of arthropod deaths occur during molting. The insect is extremely vulnerable to predators during and right after the shedding of its old skin. At this moment the insect's only protection is the soft new exoskeleton. Consequently when the molting process is initiated, insects often seek shelter and hide to decrease vulnerability to hungry predatory insects.

A large proportion of these deaths occur because of malfunctions in the molting process. The molting process requires careful timing of events and chemical balances. Errors causing appendages to become stuck in the old exoskeleton, may result in mutilation or loss of a limb, and will sometimes result in death.

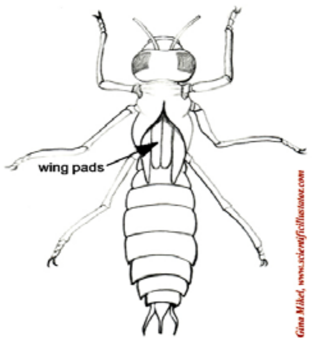
SIZE:

In regards to size, the exoskeleton serves both as a blessing and a curse for insects. The exoskeleton limits insects to their small size. There is a higher proportion of volume compared to the exoskeleton in larger insects. This higher proportion becomes dangerous right after the insect sheds its old exoskeleton because the new soft exoskeleton serves as the only structural support.

On the other hand, the small size benefits insects in that it allows them to fill ecological roles and conquer territory that larger animals cannot. Without the exoskeleton, insects would not be able to thrive at such a small size.

REGENERATION:

The insect molting process allows for regeneration of lost limbs. It is not uncommon for an insect to lose a limb. Some insects are designed to handle leg losses for escape purposes. If a predator snatches a leg, the leg can fall right off the insect and the insect can escape alive. (This is called autonomy) In the molt after such an incident, the insect leg begins the process of growing back.



TRANSFORMATION:

The exoskeletal body plan caters to large body transformations. This is especially the case with insects that do not go through complete metamorphosis such as dragonflies, stink bugs, praying mantises, and grasshoppers. These insects typically have wings as adults. Their wings develop slowly from molt to molt and can be observed as 'wing pads' during the young insects' time as a nymph. The wings are held close to the body and protected under the exoskeleton during development until the final molt occurs and the adult emerges. This transformation allows insects to spend different life stages in different niches. Eliminating competition between its own species and ensuring that if on ecosystem gets disturbed the other life stage of the species will still likely still be thriving. When the nymph stage of the dragonfly lifecycle draws to an end, the nymph climbs up out of the water onto a reed or rock and in its next molt, slips out of its old exoskeleton in the form of an adult winged dragonfly. In this transformation, the dragonfly goes from being a member of the aquatic end of the ecosystem as gilled creature to the terrestrial end as an aerial, flying predator!

UNIQUE MODIFICATIONS:

The ridged & strong nature of the exoskeleton has allowed some insects to become very complex and colorful body design. Some insects have spikes for warning and protection others have fierce predatory claws. Insects also have colorful iridescence and camouflage, which are made possible by the possession of the exoskeleton.

Praying Mantis	Raptorial front legs
Blue Morpho Butterfly	Although we see bright shiny blue, the base of the wing is not actually blue. The blue is created by the way the structure of wing bounces light around!
Spike-Headed Katydid	lives up to the name, an extremely spiky katydid. Spikes made possible by exoskeleton
Camouflaged Moth	Insects can be tricky. Many insects have modified exoskeletons which blend them into their surroundings due to their shape or the coloration or both. In the case of the image on the bottom right of this page, its both!



Overview of Exoskeleton Advantages and Disadvantages for Insects

Advantages	Disadvantage
Protection	Molting
Small Size	Limited to Small size
Body Part Regeneration	
Transformation	
Coloration	
Camouflage	
Unique modifications	

ADDITIONAL RESOURCES:

The Handy Bug Answer Book, by Gilbert Waldbauer; Nature-Ecology Visible Ink Detroit, MI (1999)

This book covers every spectrum of the insect world. The information is presented in a format that could be read cover to cover or just as a quick reference guide. This is one of the first insect focused books I owned growing up. It lives up to its name, as it is very handy. Even one of my entomology professors carries around a copy.

Insect Masquerades, by Hilda Simon; Frederick Muller Ltd, (1969).

Take a look at insects at the fun specialized trickery of insects through taking a closer looks at their traps, warning signs, and camouflage with this book.

Exploring the Insect World, by Margaret Anderson; McGraw-Hill, (1974)

Provides an insightful perspective on the insect world. It is an older book but nevertheless a good read.

Insects and spiders, explore your world handbook, by David J. Lewis and Paula Cushing; Discovery Books (2000)

This handbook provides a nice thorough run through of almost anything you would want to know about insects or spiders. There are lots of pictures, comparisons, fun facts, examples.

Scienceblog: How Insects and Crustaceans Molt (June 2010)

An article written by PZ Myers, a Biologist and associate professor at the University of Minnesota. His article provides an excellent in depth yet understandable walkthrough of the insect molting process. At the bottom is a link which has a 2 minute video of a crab molting. Check it out!

< http://scienceblogs.com/pharyngula/2010/06/how_insects_and_crustaceans_mo.php >

Insect Camouflage, North Carolina State University

I found the camouflage image of the moth from this website. There are a bunch more interactive pictures here of crazy insect shapes and colors for camouflage.

< http://www.cals.ncsu.edu/course/ent425/tutorial/Ecology/camo/ >

Chinese Mantis Final Molt 2009 – Awesome sped up footage of a complete molt to adulthood

< http://www.youtube.com/watch?v=XgmqRMa9yEM&feature=related >