# Introduction to: Why Cephalopods Change Color

By Dr. James Wood and Kelsie Jackson

"How Cephalopods Change Color" discussed the amazing ability of cephalopods to change color almost instantly. This page discusses why they have this ability and how they use it.

There are basically two reasons cephalopods change color. The first is for communication, both within species (intraspecific) as well as with other species (interspecific). The second reason is for camouflage. The ability of the cephalopods to change color is a trait that has evolved over time due to a greater need to avoid predators and become competitive in an environment shared with vertebrates. These abilities and the behaviors associated with them have become a major contributing factor to the success of the cephalopod's family, and are great examples of adaptation, both physically, through natural selection, and behaviorally.

## Camouflage

Camouflage is usually a cephalopod's primary defense against predators. As cephalopods don't have the protection of hard shells like many of their mollusk relatives, they make an easy to digest meal for a hungry predator. Therefore, most cephalopods try to avoid being seen to avoid being eaten. As well as predator avoidance, camouflage can also be used when lying in wait for unsuspecting prey to pass. Interestingly, cephalopods have more than one strategy for camouflage and these will be discussed here.

### Resembling the background

Background resemblance is the most well known form of camouflage This is when the animal changes its color and texture to match as closely as possible that of its background. Cephalopods use their chromatophores to change color to match the brightness of the environment they are attempting to blend into, and some can also change texture using muscles in their skin. Many also use different body postures to help with this. They may hold their arms in certain ways or flatten them on the substrate to become what appears to be simply part of the scenery.

### Deceptive resemblance

As well as simply trying to blend into a background, some cephalopods will attempt to make themselves appear like a specific object in their environments; this is

termed deceptive resemblance. The Caribbean reef squid, *Sepioteuthis sepioidea,* is often seen floating vertically at the surface of the water with its arms pointing downward to resemble floating sargassum weed. Some octopus may curl all their arms up into a ball, and add texture to their skin to appear like a rock. *Octopus cyanea* has also been seen swimming in a manner that makes it appear like a reef fish by swimming with all its arms together and creating false eye spots.

### Disruptive patterning

Disruptive patterning is seen in many creatures as well as cephalopods and serves to break up the outline of the animal to confuse predators. It involves the chromatophores which are used to create sharply contrasting patterns on the body, often wide stripes or spots. This is best seen in cuttlefish, who employ this technique more readily than other cephalopods.

### Counter shading

Counter shading is used to help a cephalopod blend in when there is no substrate against which to match itself. For instance, squid that spend much of their time in midwater rather than on or near the bottom can be seen easily by predators from below. Photophores and reflector cells on their underside match the light coming in through the water column, to almost make the squid invisible to animals below it. Counter shading also makes rounded surfaces appear flat. So a squid with a darker top surface, with shades gradually decreasing to a pale under surface, will be harder to spot when viewed laterally.

### Deimatic behavior

Deimatic behavior is often used when camouflage fails and the cephalopod is still threatened. It involves changing rapidly from the color it was using to blend into its environment, to bold contrasting colors such as white and black. Some species of octopus will change instantly from their mottled appearance to bright white with black around their eyes. Deimatic behavior usually also involves body postures that make the animal appear bigger than it is. If this doesn't work and the animal is still threatened, cephalopods will then usually ink and jet away.

## Communication

Cephalopods use color change as well as body postures to communicate, both with members of their own species as well as with members of other species. Many cephalopods have courtship displays in which males attempt to attract females by using chromatic displays (displays using color changes) to show that they are suitable mates. This is well developed in squid and cuttlefish but is less common in octopus in which complex courtship rituals have not yet been seen. Often during courtship males will not

only have to attempt to attract females, but also to fend off other males. As chromatophores are neurally controlled, the animal may be able to produce a pattern on one side of its body to attract a female while producing another pattern on the other side which it directs at other males. Fighting between males also exhibits a lot of communication. With squid time spent in acts of aggression involve mostly displays and very little physical contact. Squid will often show chromatic displays and body postures with increasing intensity until one backs down.

In midwater light organs and photophores are thought to be used for communication. In the same way as color is used in shallow water, bioluminescence can be used where there is less light to attract a mate, lure prey and dissuade predators.

Predator avoidance may also involve some forms of communication to the predator. As with deimatic behaviors, showing a predator that it has been spotted and attempting to make itself larger and more frightful than it is will at least often make a predator stop and think, giving vital seconds for escape. On the other hand, if the bluff is successful, the predator may back away, thinking that it is not as easy a target as anticipated.

Read “How Cephalopods Change Color”. It might be helpful in understanding how cephalopods produce the displays discussed above.

# Why Cephalopods Change Color- Teacher Resource

By Dr. James Wood and Kelsie Jackson

## Abstract

"Why Cephalopods Change Color" allows students to investigate how cephalopods use their amazing abilities for color change to their advantage. Students learn about the ways in which cephalopods use camouflage and how they communicate through use of color change, light reflection and light production cells. The various strategies for camouflage are discussed as well as the different types of communication. Behavioral strategies and body postures are also investigated as a means for communication and camouflage. Students learn how the cephalopod's abilities for color change allow it to remain competitive when most do not have aggressive defensive strategies.

## Objectives

- To allow students to investigate the various ways cephalopods use body postures and color change to camouflage and communicate.
- To examine how these adaptations aid cephalopods in their daily lives.

## Introduction

This web resource is an excellent follow up from the "How Cephalopods Change Color" pages. It discusses how cephalopods utilize their abilities to achieve camouflage and communicate with one another and with other species.

There are a few different strategies that cephalopods may use to achieve camouflage. These include background resemblance, deceptive resemblance, disruptive patterning and counter shading. Some species will use more that one strategy at once, while others have a tendency to use only one. Background resemblance is usually what people think about when they think of the meaning of camouflage. This is basically when the cephalopod attempts to blend into its environment by changing its color and texture to match that of its surroundings. It is quite common in many species, particularly shallow water benthic species. Deceptive resemblance is an attempt to use color, texture and body postures to imitate objects in the environment such as rocks, corals or floating algae. Disruptive patterning is often used by some species of cuttlefish as well as other cephalopods to break up the shape of the body to appear less conspicuous or confuse predators. It often involves the creation of wide bands of color or spots on the animal's skin by use of chromatophores or leucophores. Counter shading is often used by midwater species that do not have a background against which to camouflage. It may employ the use of reflector cells or photophores on the underside to counter down welling

light and make the animals less visible from below. It may also involve producing a dark color on the skin of the upper surface, which fades to a pale underside as this makes the animal appear less rounded and harder to see laterally. Deimatic behavior is sometimes used when camouflage fails. This is usually a secondary defense strategy where the animal will suddenly flash contrasting colors such as white and black and attempt to make itself appear larger than it is to scare off, or confuse predators.

There are many forms of communication in cephalopods that involve the use of color change, body patterning and body postures. Courtship often involves the extensive use of displays in squid and cuttlefish; however, octopus appear to have less display orientated courtship rituals. Patterns, colors and postures are all used to attempt to attract a mate and often used to dissuade competitors at the same time in some species. Deceptive communication is sometimes seen between cephalopods and their predators. For instance, deimatic behavior may be an attempt to communicate that the cephalopod is not an easy target, that the predator has been spotted, or simply to confuse an attacker. Communication within species is not well understood, but it is thought that in some species of squids that school, sentinels will warn other members of danger. Some species of cuttlefish have been seen to give off polarized light in a way that can be controlled, and it is known that these animals can see both polarized and unpolarized light, which has lead to the suggestion that this may be a means of intraspecific communication which predators cannot see. Displays of aggression are common among cephalopods; one of the most stunning being the zebra stripe display in cuttlefish. Aggressive male squid, when competing for a mate, will often produce displays and patterns with more and more intensity until one backs down. Often in these animals the use of displays make up most of the time spent with an opponent; physical aggression appears to be much less important.

## Key Concepts

- Color change is used for two main functions: camouflage and communication
- There are different strategies for achieving camouflage.
- Communication can occur within as well as between species by use of color change and body postures.

## Student Learning Objectives

- To understand the different strategies for achieving camouflage and the ways in which color change and body postures are used in this respect.
- To investigate different types of communication in cephalopods and how this occurs by way of color change and body postures.

## Conclusion

After using the “Why Cephalopods Change Color” page and participating in class discussion, students will understand how cephalopods use color change to their advantage in their daily lives. They will have learned what the various strategies for camouflage are, and how these are often a cephalopod’s primary defense against predators. They will understand how color change and body postures are used in the many forms of communication seen in cephalopods including mating displays, aggressive displays, and displays used to confuse or ward off predators. Students will know that color change is a vital aspect of the lives of many cephalopods and is a large part of the reason for the success of this family.

# Web Resources and Bibliography

- Link to CephBase video showing an octopus camouflaged and then displaying deimatic behavior

http://www.cephbase.utmb.edu/viddb/vidsrch3.cfm?ID=132&CephID=

- Link to CephBase image database

  - Octopus showing background resemblance

http://www.cephbase.utmb.edu/imgdb/imgsrch3.cfm?ID=161&PhotographerID=&CephID=&Location=&Keywords=&LowestTaxa=

  - Cuttlefish showing zebra display, male aggressive display

http://www.cephbase.utmb.edu/imgdb/imgsrch3.cfm?ID=319&PhotographerID=&CephID=&Location=&Keywords=&LowestTaxa=

  - Juvenile squid using disruptive patterning

http://www.cephbase.utmb.edu/imgdb/imgsrch3.cfm?ID=524&PhotographerID=&CephID=&Location=&Keywords=&LowestTaxa=

  - Cuttlefish with textured skin

http://www.cephbase.utmb.edu/imgdb/imgsrch3.cfm?ID=813&PhotographerID=&CephID=&Location=&Keywords=&LowestTaxa=

  - Camouflaged octopus

http://www.cephbase.utmb.edu/imgdb/imgsrch3.cfm?ID=990&PhotographerID=&CephID=&Location=&Keywords=&LowestTaxa=

- For more information see

Hanlon R.T. & Messenger, B. (2003) *Cephalopod Behaviour*, Cambridge University Press, Cambridge.

# Vocabulary

Bioluminescence: Occurs in the light producing organs known as photophores--usually due to a chemical reaction inside the photophore. In some species bioluminescence is produced by luminescent bacteria contained in sacs in the body.

Camouflage: Concealment by way of blending into an environment, either by using materials from that environment or as in the case of cephalopods, changing color and texture. The word crypsis may be used when discussing camouflage, which is thought to encompass the behavioral aspects of concealment as well as the physical changing of color, but without the use of materials from the environment.

Chromatic displays: Displays involving color change by use of chromatophores, as opposed to postural displays where the cephalopod will position its body and arms in a certain way to convey something.

Chromatophores: Organs responsible for color changes in cephalopods. Each chromatophore is made up of a sac containing pigment, as well as muscles, nerves and other cells. Since the sac has elastic walls, it can be stretched by use of muscles to show more pigment.

Interspecific: Between different species, i.e. interspecific competition; competition between members of different species.

Intraspecific: Within the same species, i..e. intraspecific communication; communication between members of the same species.

Photophores: Light producing organs involved in bioluminescence. Sites where the light producing chemical reaction occurs.

# Frequently Asked Questions

## Question

## How fast can they change colors to avoid predation?

The first line of defense is never to be seen! If this doesn't work, it takes less than a second for a retracted chromatophore to expand completely (Hill & Solandt 1935). Therefore, when faced with a predator, cephalopods may show four of five body patterns within a few seconds; presumably to startle or confuse it (Hanlon & Messenger 1996).

## Question

## What kind of changes they do make to avoid predation?

Cephalopods can change their coloration in several ways. Background resemblance is the most well known form of camouflage. This is when the animal changes its color and texture to match as closely as possible that of its background. As well as simply trying to blend into a background, some cephalopods will attempt to make themselves appear like a specific object in their environments; this is termed deceptive resemblance. Disruptive patterning is seen in many creatures as well as cephalopods and serves to break up the outline of the animal to confuse predators. Counter shading is used to help a cephalopod blend in when there is no substrate against which to match. Deimatic behavior is often used when camouflage fails and the cephalopod is still threatened. It involves changing rapidly from the color it was using to blend into its environment, to bold contrasting colors such as white and black.

Q: Do Cephalopods change color for offense as well as defense?

A: Cephalopods will change color during feeding events in attempts to lure or mesmerize their prey.

Q: Apart from offense and defense, why else do Cephalopods change color?

A: Cephalopods can transmit signals about identity, ability and motivation in the sexual domain indicating competence to mate (i.e., courtship) and fighting ability (Hanlon & Messenger 1996).

## Materials & Activities

Students will conduct two activities in this module.

Activity #1 is designed to help them understand how camouflage aids survival so that an organism can reach sexual maturity and increase the likelihood of reproducing. They will be participating in a bean camouflage activity where each successive trial represents another generation. The purpose of this activity is to show how camouflage will aid in the bean's survival from the student predators.

Activity #1 Materials

- Black poster board for half the students in the class
- White poster board for the other half of the students in the class
- Black beans
- White beans
- Container such as a beaker or cup to mix the beans
- Paper and pencil to complete the data table for bean camouflage

Activity #2 is designed to have students learn how to observe squid behavior by using actual photographic images from the CephBase website as well as Dr. Woods' personal collection. Students will match photographic images with captioned descriptions of squid behavior. The idea behind this activity is to have students understand why cephalopods change color. Due to these changes in color, camouflage is often compromised, however.

Activity #2 Materials

- Color photos of the pictures from the website and from Dr. Woods' personal photographic collection listed below
- Paper and pencil to complete the matching activity

# Answers Student Activity #1 Why Cephalopods Change Color

## Bean Camouflage Activity

Students' results will obviously vary within their data table as the numbers of beans being removed will not be consistent.

## Analysis Questions Analysis Questions

1. What happens to the number of black beans on the black background over the course of the trials?

   Black background will favor survival of black beans because the white beans will be selected by student predators. The line graph should indicate an upward survival curve for the black beans and a downward one for the white.

2. What happens to the number of white beans on the white background over the course of the trials?

   White background will favor survival of white beans because the black beans will be selected by student predators. The line graph should indicate an upward survival curve for the white beans and a downward one for the black.

3. How does camouflage affect survival rate?

   Camouflage increases the chances of surviving to reach sexual maturity and produce offspring

# Answers Student Activity #2 Why Cephalopods Change Color

## Analysis Questions

1. Based on this matching activity with actual photographic images of squid, what are some of the reasons why squid change color?

   Squid change color to communicate within their species, to other species (eye spot photo) and camouflage (avoiding predation as well aiding in capturing prey).

2. How does the visibility of the squid differ between communication mode and camouflage mode?

   In the communication mode they are highly visible so that they can be recognized by their species; however, this makes them much more visible to their predators.

3. How does communication interfere with camouflage?

   It hinders camouflage. It is hard to send a message and not be seen at the same time.

| Descriptive Captions | Image # |
|---|---|
| A. This squid has two false eye spots on his body. Squid can orientate perpendicular to predators and stretches out its mantel and fins making it look larger. It also flashes 2 or 4 eye spots. In this case, the signal was directed at me as I was getting too close with my camera! | **2** |
| B. This pair of squid is courting. The upper squid is a female and is making a highly visible display which we believe signals interest to the male squid. | **5** |
| C. Body posture is important for this squid. The squid is in the water column away from the bottom. The squid is away from other squid. To us, the arm posture of the squid make it appear as a floating piece of algae. | **1** |
| D. This Caribbean reef squid is double signaling, one side of his body is white while the other side is brown. | **4** |
| E. This image shows two males competing over access to females. The zebra displays are highly visible. | **6** |
| F. The two upper squid in this image are camouflaged and match the background well. | **7** |
| G. Body posture is important for this squid. From a distance, the orientation, position and dark lateral lines make this squid appear as part of the soft coral. | **3** |

# Student Activities: Why Cephalopods Change Color #1

**By Brian Goldstein, Valerie Cournoyer, Roger E. Goss, Nancy W. Goss, and Dr. James B. Wood**

## Activity

Students will perform an experiment showing the importance of camouflage on predator avoidance.

## Description

By using black and white beans on either a black or white background, students will determine the survival rate of one color bean or the other. Students will graph the results of the five trials, determining the independent and dependent variables. Students will analyze their results.

## Materials & Activities

- Black poster board for half the students in the class
- White poster board for the other half of the students in the class
- Black beans
- White beans
- Container such as a beaker or cup to mix the beans
- Paper and pencil to complete the data table for bean camouflage

## Procedure

1. Take the poster board your lab group has been given and lay it down on a lab table.
2. Count out 50 black beans and 50 white beans.
3. Place both sets of beans in a container and mix up by cupping your hand over the top of the container.
4. Carefully distribute the beans in a random manner over the surface of the poster board.
5. Quickly pickup at random half of the beans off of your poster board. You will be given a very short time in which to do this. This will not be exactly half of the beans but rather an approximation by eye of half of the beans. One member of your group will determine when half of the beans remain. (Trial 1)

6. Record on the data table the results of trial one as a percent of the remaining black and remaining white beans.
7. Double the remaining bean number for each color from trial one.
8. Repeat steps 3-5. Record data as Trial 2.
9. Repeat this procedure until you have completed 5 trials on the data table.
10. Make a line graph of the results of your experiment. Determine the independent and dependent variables. See Line Graph Evaluation Tool (link to light and color module).

**Table for Bean Camouflage**

| Trial # | Remaining Beans | | Remaining Beans | |
|---|---|---|---|---|
| | Black | | White | |
| | Number | Percentage | Number | Percentage |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |

## Analysis Questions

1. What happens to the number of black beans on the black background over the course of the trials?

2. What happens to the number of white beans on the white background over the course of the trials?

3. How does camouflage affect survival rate?

# Student Activities: Why Cephalopods Change Color #2

**By Brian Goldstein, Valerie Cournoyer, Roger E. Goss, Nancy W. Goss, and Dr. James B.Wood**

## Activity

Students will observe the different strategies for achieving camouflage in cephalopods by using the photographic images from the CephBase website and from Dr. Woods' personal photographic collection.

## Description

The CephBase website contains 1,642 photographic images and 144 videos of cephalopods. Using selected photographic images listed from the CephBase site and from Dr. Woods' personal photographic collection in the activity below, students will view cephalopods of the same species to match the descriptive behavior contained in the captions for the photos.

## Materials & Activities

- Color photos of the pictures from the website and from Dr. Woods' personal photographic collection listed below
- Paper and pencil to complete the matching activity

## Procedure

1. Below are the numbered photographic images. Practice observation skills by viewing photographic images of cephalopods.
2. Match the photographic image to the descriptive caption. Record your answers in the space provided.
3. Each photographic image and each caption can only be used once.

# Images from CephBase website & Dr. Wood


**Image 1: Photo by John Forsythe**


**Image 2: Photo by James B. Wood**


**Image 3: Photo by John Forsythe**


**Image 4: Photo by James B. Wood**


**Image 5: Photo by James B. Wood**

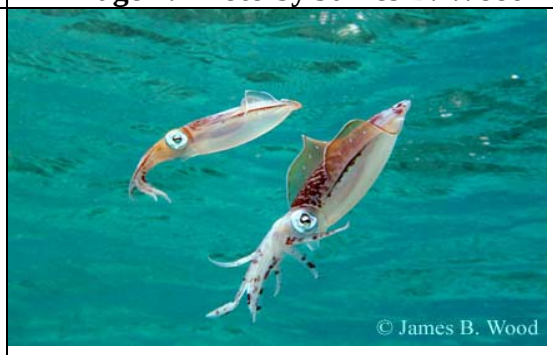


**Image 6: Photo by James B. Wood**


**Image 7: Photo by Ruth Byrne**

| Descriptive Captions | Image # |
|---|---|
| A. This squid has two false eye spots on his body. Squid can orientate perpendicular to predators and stretches out its mantel and fins making it look larger. It also flashes 2 or 4 eye spots. In this case, the signal was directed at me as I was getting too close with my camera! | |
| B. This pair of squid is courting. The upper squid is a female and is making a highly visible display which we believe signals interest to the male squid. | |
| C. Body posture is important for this squid. The squid is in the water column away from the bottom. The squid is away from other squid. To us, the arm posture of the squid make it appear as a floating piece of algae. | |
| D. This Caribbean reef squid is double signaling, one side of his body is white while the other side is brown. | |
| E. This image shows two males competing over access to females. The zebra displays are highly visible. | |
| F. The two upper squid in this image are camouflaged and match the background well. | |
| G. Body posture is important for this squid. From a distance, the orientation, position and dark lateral lines make this squid appear as part of the soft coral. | |

## Analysis Questions

1. Based on this matching activity with actual photographic images of squid, what are some of the reasons why squid change color?

2. How does the visibility of the squid differ between communication mode and camouflage mode?

3. How does communication interfere with camouflage?

# Acknowledgments

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