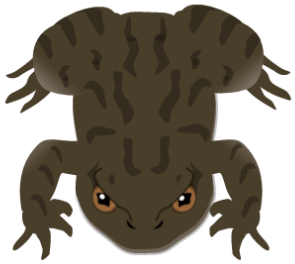
Camouflage and Adaptation



Aim: *Investigate the role of evolution in animals adapting to be camouflaged to their environment.*

1) Introduction

Camouflage is the art of concealing oneself by being more difficult to spot or disguising as something else. Many animals have camouflage as it is a useful ability for sneaking up on prey or avoiding being eaten.

Toads are a fantastic example of a group of animals which live in many different environments from bogs to deserts and jungles. One feature that you might have noticed when looking at animals, is that their colour and pattern varies depending on the environment they live in. This is especially true for animals that use camouflage, as camouflage depends on being similar to the environment, making it a great example of adaptation. But what enables this adaptation?

Example camouflage in toads.

2) Exercise

What you're doing

In this practical you will learn how animals such as toads develop camouflage by the process of evolution by natural selection. To do this you will simulate evolution in real time! Taking on the role of a toad's predator. All you will need is the following:

- *A phone or camera (optional)*
- *A computer or laptop*
- *Access to the internet*
- *CamoEvo Installed*

To simulate evolution, you will need to:

Pick a habitat: This can be any habitat, your back garden, the school yard or one of the sample habitats (bog, scrub, woodland). This should be a habitat where a toad could feasibly live.

Get a photo: Get a photo of the habitat or use one of the examples. To take the photo you need it to be a bird's eye view of the ground.

Make a prediction: Have a think about what sort of pattern or colour you would expect a toad to be if it lived in that habitat and needed to be camouflaged. Would it be brown or green? Would it have spots or stripes?

Play CamoEvo: Once you have your photos you can simulate how a population of toads might evolve in that habitat by evolution.

Example Habitats (DOWNLOAD)

Woodland: a habitat consisting of leaflitter with lots of brown and orangey colours.

Wetland: a habitat consisting of muddy patches and long grasses.

Scrubland: a sandy gravelly habitat with short patches of grass.

3) Simulating Evolution

Evolution requires three key ingredients, **heritability and variability** and **selection**.

Organisms within a population need to be able to replicate producing offspring that ***inherit*** the appearance (traits) of their parents. Think about things like eye colour and hair colour in humans, and how people who are members of the same family look similar to one another.

They also need to ***vary*** in their traits. Variation comes from mutations during replication. Think of mutation as like making a photocopy. If you kept on photocopying something, then photocopying the photocopy. Eventually an error will occur where the photocopy doesn't come out quite right, and that error will be present in all future photocopies. But in species that reproduce sexually additional variation comes from the crossover of genes from parents, with the offspring inheriting traits from both parents.

In order for evolution to change what animals look like there must also be a source of ***selection!*** Not all animals get to survive and many die due to starvation or predation. Individuals with traits which make them better at surviving and reproducing are more likely to be passed on. Individuals with such traits are said to have a higher fitness. Hence the iconic phrase 'Survival of the Fittest'.

In the game that you are going to play you will simulate how **heritability, variability** and **selection**, can lead to EVOLUTION! To do this you will start with a random population of different looking toads. With each generation the toads that are easier to find will die! This removes them from the population. While the toads that take longer to find get to survive and breed. This way with each generation more and more individuals should gain the beneficial traits, in this case the trait should be camouflage and new variations can occur through mutation. The offspring produced in each generation are made by pairing the survivors and producing recombinant offspring with mutation. Each generation consists of the new individuals born in that generation and the survivors from the previous generations.

So in short, you are evolving toads in a habitat you've chosen by using detection time as the measure of fitness.

Step 1

Download CamoEvo!

If CamoEvo isn't already on the device you are using, you will need to download it.

Click **HERE** to download for Windows.

Click **HERE** to download for Mac.

Once downloaded, Unzip by right clicking and clicking send to extract (windows).
Then run CamoEvo by double clicking the CamoEvo (ImageJ).exe file.

Step 2

Copy Photo to Folder.

Copy the photo you took/chose to a folder that you know the location of and call the folder Habitat.

Step 3

Run CamoEvo

Launch CamoEvo: Go to the CamoEvo main menu.

Create a New Game: Click *New Game* and then click *get photos*. Choose the folder you named Habitat. (if you hit cancel, you will need to reopen CamoEvo). You will then be asked to choose what prey you will use. For this practical select *Animals* and then *Toads*. You will then be presented with the option to choose advanced settings, select *No*. Then *Name* your population after the habitat you chose *e.g. WetlandToads* (no longer than 15 characters).

Playing the Game: Once you have named your population the game will start to generate the first generation of toads. This generation consists of 24 completely random individuals. Generation may take between 1-2 minutes depending on the speed of your computer.

What CamoEvo looks like, UI and spot the Toad.

You will then be tasked with finding and capturing each toad as quickly as you can by clicking on them. Once all the toads are found the next generation will develop by killing off the 12 worst individuals and replacing them with the offspring of the 6 best individuals. Those who are in the middle don't get to breed but don't die either.

Finishing the Game: Once you have completed 5 generations the game will finish and present you with screen asking if you want to analyse your results or keep going. Click analyse and wait for CamoEvo to output its data (should take only 5 minutes). *Use this time to think about how the population of toads changed, did they get harder to spot and were they more camouflaged?*

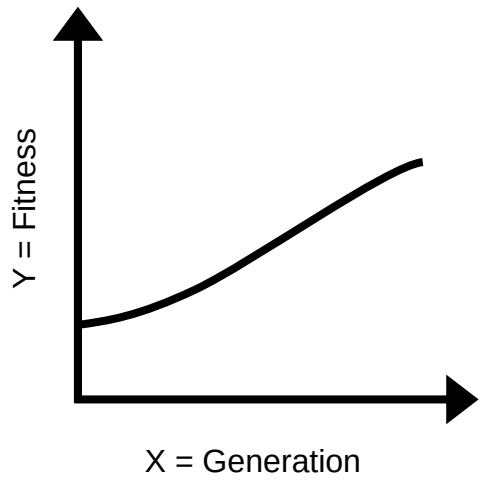
Results Preview: You will now be presented with a result preview menu. Here you will see a plot of how long it took to find the toads on average with each generation in addition to the hardest to find toads from the most recent generation.

4) Understanding your Results

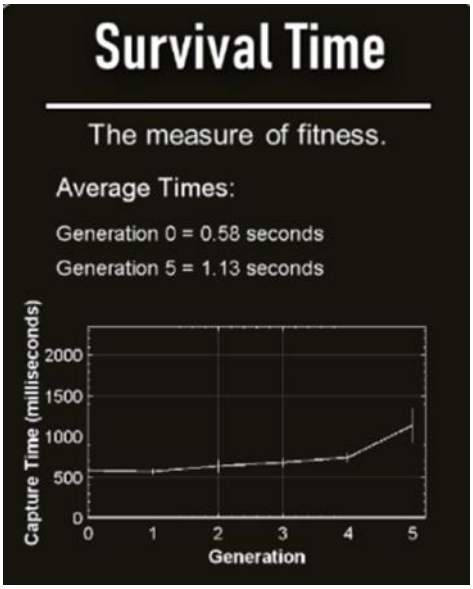
Measuring Evolution

If your toads have successfully started to evolve camouflage you should expect the measure of fitness (survival time) to improve with each generation. Note if there is no difference this doesn't mean evolution isn't taking place.

Expected Plot



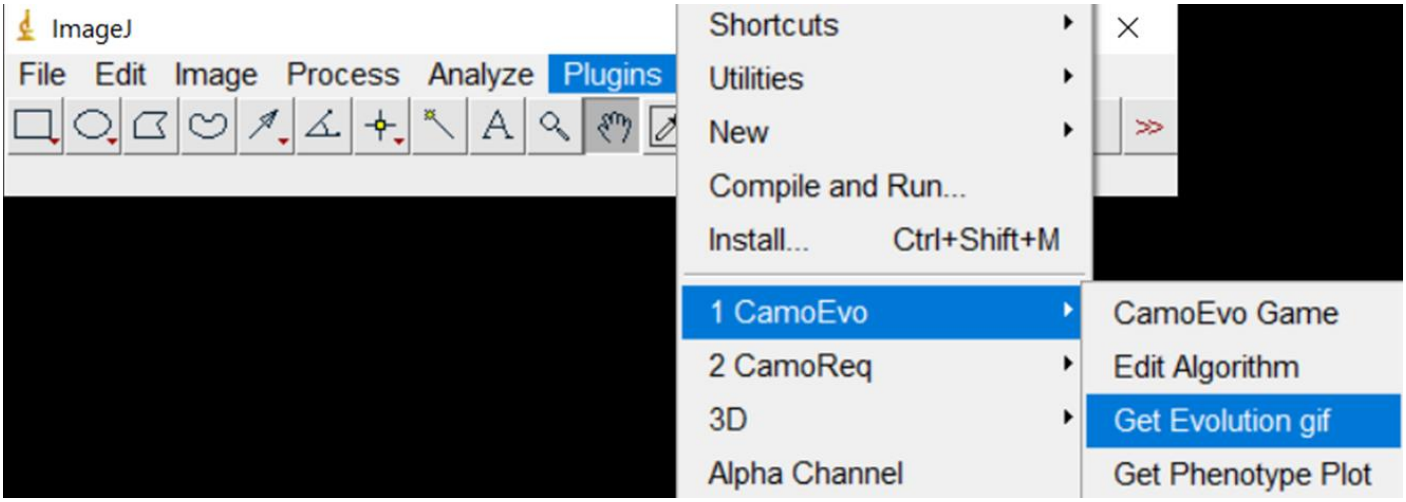
Actual Plot



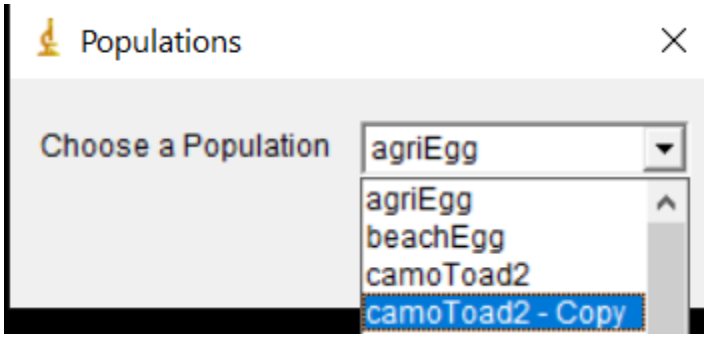
For example. Here the survival time has increased from an average of 0.58 to 1.13 and the graph also shows an upward increase in survival time (fitness) with generation.

If you' like you can also view how the population has changed in appearance. Exit the menu and then using the ImageJ tool bar you can create a plot showing all your toads. Just follow these Instructions:

1) **Select Get Evolution Gif**

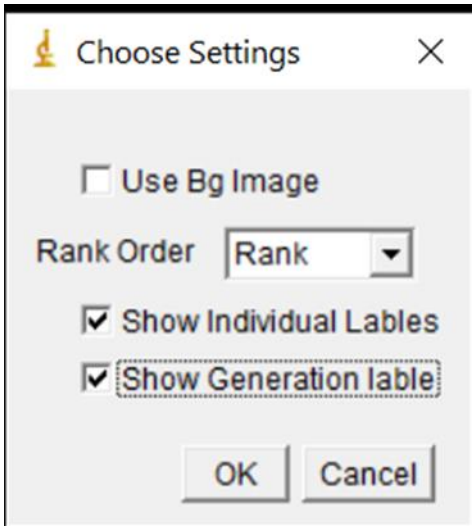


2) **Select your population**, click on the population you named



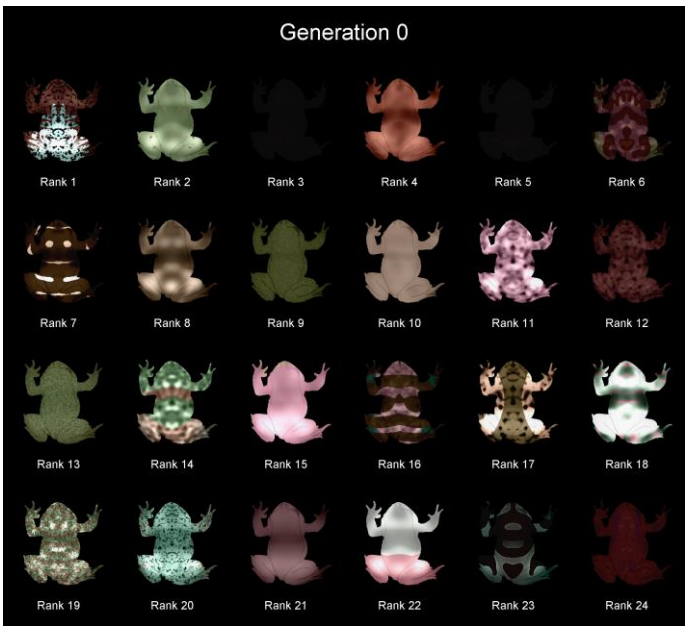
3) **Adjust the settings,** turn on the individual and generation labels, and order by category

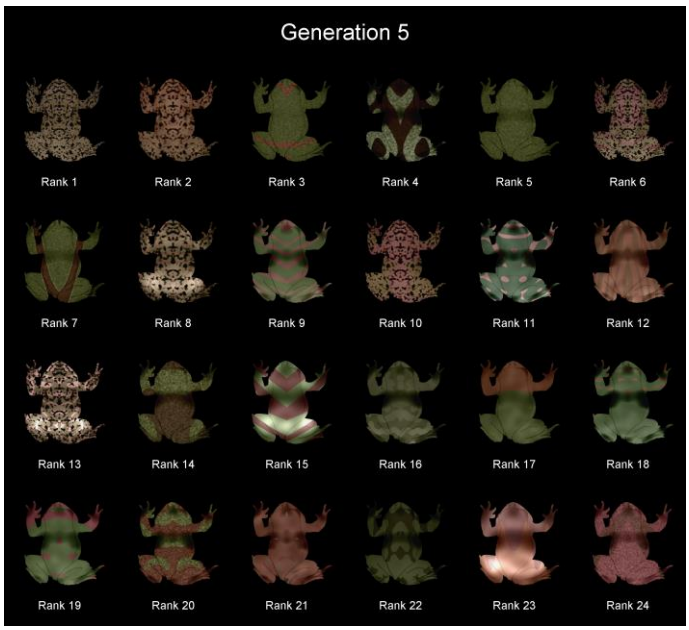
Ordering by rank means the survivors will be positioned on top and those who are killed off are shown on the bottom. Alternatively you can order by category *which shows the parents on the top and the offspring on the bottom.*



4) **Watch the evolution,** click ok and then watch it show you the evolution.

Ranks 1-12 live and Ranks 13-24 die. Only Ranks 1-6 get to breed. But 7-12 can have another chance next generation





Measuring Camouflage (Advanced**)**

Camouflage relies on two things. Being similar to your background making you more difficult to make out or disguising yourself as something that a predator isn't interested in such as leaves and twigs. The technical terms for these mechanisms are **crypsis** (looking like your background) and **masquerade** (disguising yourself)

Toads showcasing crypsis (left) and leaf masquerade (right)

But how do you actually measure these. Measuring masquerade is complicated and would require measuring the similarity between the toad and other recognisable objects. However, we can measure how similar the toad is to its background (the more similar, the more camouflaged) and how much the pattern of the toad breaks up its outline.

Measures of *Match!*

To reduce the likelihood of being spotted animals need to be similar to their background. This similarity is based on the information available to what is looking at the animal. In this case the information is what the observer/predator can see!

To measure match, we break down the appearance of the toad into simple components that are relevant to how animals see and gain information from the world.

Luminance Match, one of the most important aspects of a background to match is luminance. Luminance being how bright and dark the animal is. Just about every animal with eyes is able to distinguish differences in luminance, while not all animals can see colour or the same range of colours. *Look at the toads above, which is easier to make out and why?*

CamoEvo measures the *mean luminance* of the toad and of the surrounding background. The *lower* the *difference* the better the camouflage.

Contrast Match, contrast is the measure of difference in luminance within the animal itself, with a greater deviation resulting in a higher contrast. Animals with high contrast patterns are ones which have more light and dark patches, while those with low contrast have more faint patterns. *Look at the toads above, which is easier to make out and why?*

CamoEvo measures the *standard deviation of luminance* of the toad and of the surrounding background. The *lower* the *difference* the better the camouflage.

Colour Match, the animals which typically hunt toads are able to see colour, though which colours they can see varies from species to species. While humans can't distinguish colours as easily as luminance our colour discrimination is better than most animals and is very useful for spotting things. *For example, think just how much colour is used in everyday life to make things more obvious. Imagine if the only difference in traffic lights was how bright they are.* Humans are able to see three colours red green and blue, all other colours are a mixture of the three.

Look at the toads above, which is easier to make out and why?

CamoEvo measures the *mean colour* of the toad and of the surrounding background, based on human colour vision. The *lower* the *difference* the better the camouflage.

Measures of Recognition!

Matching your background is fine and all but animals also have to contend with another issue, SHAPE. Animals typically aren't shaped like their background and the toads in this game do not vary in shape (i.e., shape isn't a trait). As a result, even if they have a similar pattern to their background they may be given away by their outline.

To avoid this, animals that camouflage often have lots of contrasting patterns around their edges (sides, arms and legs) in order to break up their shape making them more difficult to detect.

GabRat
(Edge Disruption)

Edge Disruption, edge disruption is the technical term for the method by which animal patterns break up their outline making them more difficult to detect. Animals which have more contrasting patterns around their edges typically are more disruptive.

CamoEvo measures the *GabRat* of the toad against its surrounding, a method developed by the Universities of Exeter and Newcastle for measuring edge disruption. The *higher* the *GabRat* the more effective the camouflage should be.

5) Questions

Q. "What test would you use to prove that fitness increased with generation?"

Q. "Did fitness improve with generation? If so, why do you think that was?"

Q. "Did camouflage improve with generation? If so, why do you think that was?"

Q. "Do you think camouflage would be different on a different habitat, if so why?"

Q. "If fitness didn't improve very much, what factors could have influenced this?"

Q. "What do you think would happen if toads with faster times were selected for?"

For answers see the next page.

6) Answers

Q. "Did fitness improve with generation? If so, why do you think that was?"

A. *Because the population is under selection for fitness to improve resulting in the population evolving a higher fitness. The population can evolve this higher fitness as the offspring produced by recombination are fitter than their parents (possess a better combination of traits), and mutations introduce new and better traits.*

Q. "Did camouflage improve with generation? If so, why do you think that was?"

A. *Because camouflage is what increases survival time, so even though survival time is the measure of fitness used by CamoEvo, traits that make the phenotype of the animal more camouflaged are what are actually being selected for.*

Q. "Do you think camouflage would be different on a different habitat, if so why?"

A. *Yes because camouflage is dependent on matching the local environment of the animal. So different habitats will require different camouflage patterns and strategies.*

Q. "If fitness didn't improve very much, what factors could have influenced this?"

A. *There are a few things that can cause this.*

If camouflage improves but fitness doesn't then it may be simply that the predator (you) are learning how to find the toads faster than the toads can evolve, meaning that you can keep up with it.

If camouflage does not improve either then it may be the case that none of the individuals in the starting population were camouflaged at all, so there are no beneficial traits to begin with.

Q. "What do you think would happen if toads with faster times were selected for?"

A. *In this case toads should become more brightly coloured and easier to see with each generation.*