The Variety of Birds' Eggs

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Béatrice and Kurt Schläpfer are measuring the colour of an egg-shell.

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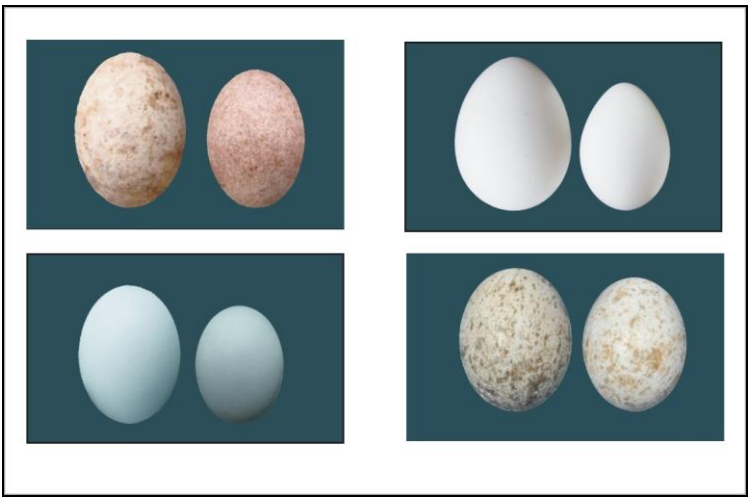
The variety of birds' eggs

It is a matter of common knowledge that all birds are laying eggs. If birds were live bearing, the embryo to be carried in their body would obviously impact their ability to fly. The fact that there are also flightless birds, such as the Ostrich, is a consequence of the evolution, meaning that all birds were originally capable of flying.

The variety of eggs is primarily given by the number of bird species. This raises the question as to how many bird species exist. Interestingly enough, this number is not clearly defined. Classifications differ from each other, depending on whether similar birds are grouped into the same species (and listed as subspecies) or assigned to different species. Therefore different approaches result in a varying total number of bird species. A number that can be easily kept in mind and which is in good agreement with the currently used classifications is 10,000. But the number of different birds' eggs is even higher than the number of classified bird species. As an example, there are around 200 chicken breeds, which all are descended from only one bird species, i.e. the Red Junglefowl (*Gallus gallus*). Chickens produce very different eggshell colours, such as the bluish green egg of the Araucanas or the dark brown egg of the Marans. Even the same bird species may lay eggs of different appearance. An example for this is the Cuckoo (*Cuculus canorus*), which is a so-called nest-parasite. Instead of constructing their own nests, they lay their eggs in the nests of other species. This is only possible because the coloration of the Cuckoo egg is matching the eggs of the host bird. Thus, there are as many different Cuckoo eggs as host birds chosen

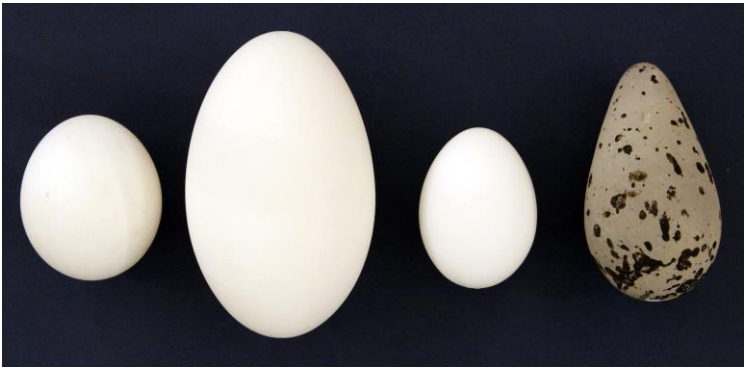
by the Cuckoo. In Europe, popular host birds are the European Robin, the Black Redstart and the Common Redstart.



Cuckoo eggs together with the egg of the corresponding host bird:
Top left: Tree Pipit
Top right: Black Redstart
Bottom left: Common Redstart
Bottom right: European Robin
(The cuckoo egg is always the larger egg on the left.)

In 1967, the well-known German oologist Wolfgang Makatsch published a booklet entitled "No two eggs are alike". However, this statement may not seem appropriate, as eggs of different bird species indeed look alike to many people. For example, the white eggs of some pigeon species are hardly distinguishable from those of some parrots regarding both shape and size. But generally speaking, there are a number of criteria in which birds' eggs can be different. Wolfgang Makatsch points out, for instance, that not all eggs are egg-shaped. In the literature, eight basic shapes are distinguished. Apart from the conventional egg-shape, especially ball-shaped eggs (for instance

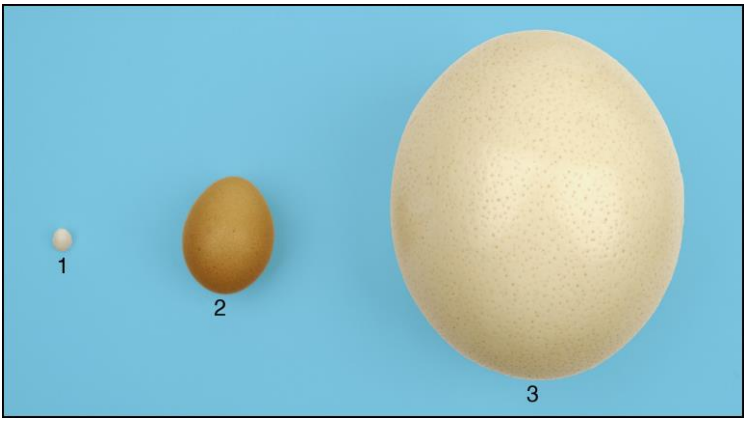
of the Ruddy Kingfisher) and cone-shaped eggs (for instance of the Puffin) are noticeable. The shape of the eggs can even be of vital importance for the survival of the embryonic chick. This is the case with the conical eggs of the Common Murre, because this shape allows the eggs to roll around rather than rolling off the cliffs on which they are laid.



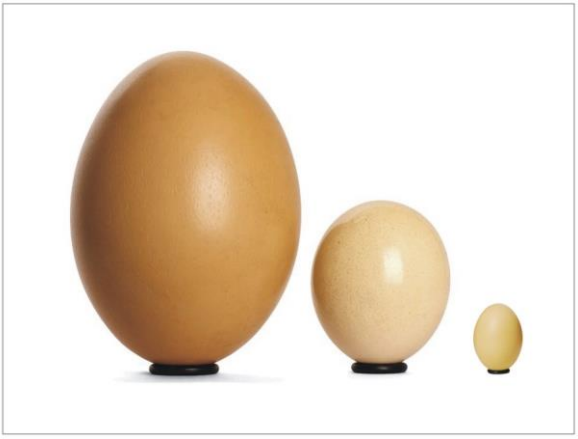
Different egg shapes:
ball-shaped (Eurasian Eagle-Owl)
elliptical (Whooper Swan)
egg-shaped (domestic chicken)
cone-shaped (Common Murre)

A very eye-catching characteristic of birds' eggs is their size. It is generally known that the Ostrich lays the largest eggs, whose weight is around 1.5 kg. At the other end of the scale are different bird species, particularly the hummingbirds with over 300 species. The smallest hummingbird eggs weigh about 0.2 g, meaning that one Ostrich egg is equivalent to 7500 hummingbird eggs. The common chicken egg has a weight between 50 g and 80 g. Thus, an Ostrich egg corresponds to at least 20 chicken eggs. It seems obvious that small birds lay small eggs and vice versa. But this is not a strict rule. If the weight of the egg is compared to the weight of the bird, this ratio varies between 2 % (in case of the Ostrich) and 10 % for

small birds. A notable exception, however, is the Kiwi (the heraldic bird of New Zealand), whose eggs may amount up to 25 % of its body weight.



Variations in egg size: Hummingbird (1), domestic chicken (2) and Ostrich (3)
(Hummingbird species: Calypte anna)



Chicken egg and Ostrich egg compared with the egg of the extinct Elephant Bird (right to left)

Even larger eggs have been laid by the so-called Great Elephantbird (*Aepyornis maximus*), a flightless bird native in Madagascar and extinct since 450 years. Thanks to their robust eggshell, a number of intact or only slightly damaged eggs have been preserved. The weight of an egg (including egg white and yolk) is almost 10 kg, corresponding to around seven Ostrich eggs. It is estimated that about 100 eggs of the Great Elephantbird still exist worldwide.

Probably the most impressive attribute of avian eggs is the coloration. But not all birds lay coloured eggs. There are complete bird families laying immaculate white eggs, for instance:

- the parrots (360 species)
- the pigeons (313 species)
- the hummingbirds (322 species)
- the woodpeckers (216 species)
- the owls (156 species)

It may be guessed that up to a fourth of all bird species produce completely white eggs.

White eggs can appear very differently. Very white eggs are laid by the White Stork *(Ciconia ciconia)*. Ostrich eggs are usually regarded as white eggs, but their coloration has rather to be described as creamy. They only appear white when surrounded by brownish desert sand.

There are no birds laying truly black eggs. The darkest eggs are laid by the Emu *(Dromaius novaehollandiae)*, a flightless bird living in Australia. These eggs are dark green or dark blue, but the coloration darkens when stored during years in collections and, eventually, they may look almost black. Moreover, there are spotted eggs with some spots appearing nearly black.

Coloured eggs appear in many shades, ranging from pale to vivid colours and from dark to bright tones. Saturated colours occur mainly in the green-blue and red-brown hue range. Especially one bird family features very strongly coloured eggs: These are the tinamous (*Tinamidae*) living in South and Middle America. Their eggs have a glossy shell surface similar to glazed china.

Curve-billed Tinamou

Great Tinamou

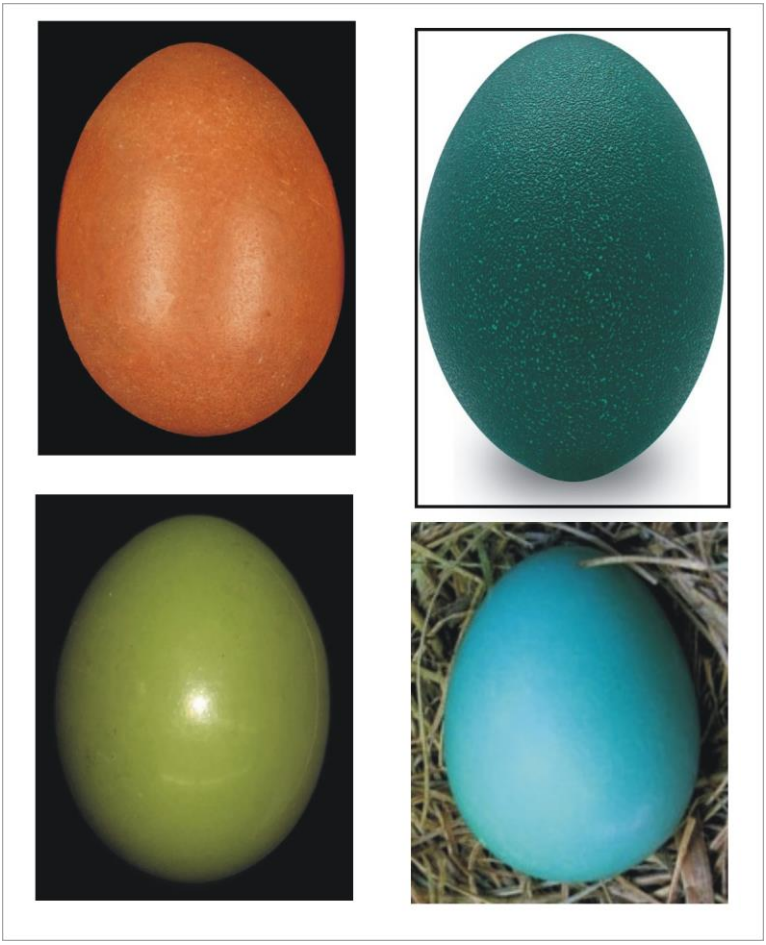
Chilean Tinamou

Chaco Tinamou

Elegant crested Tinamou

Hooded Tinamou

The conspicuous coloration of the eggs of some tinamou species



Examples of eggs with bright colours:
Red-brown: Cetti's Warbler
Dark-green: Emu
Green: Elegant crested Tinamou
Blue: American Robin
For a better comparison of their coloration, the eggs are not shown in the correct size relationship.

However, there are colour shades that cannot be found on avian eggshells, for instance pure yellow, saturated red tints and colours in the violet and purple range. This is a very astonishing fact in view of the colour richness occurring elsewhere in the nature. One example of many is the colour variety found within the family of parrots. But the limited colour range found on avian eggshells can easily be explained: There are only three pigments responsible for the eggshell colours. How the colour is added to the eggshell is explained in a later chapter.

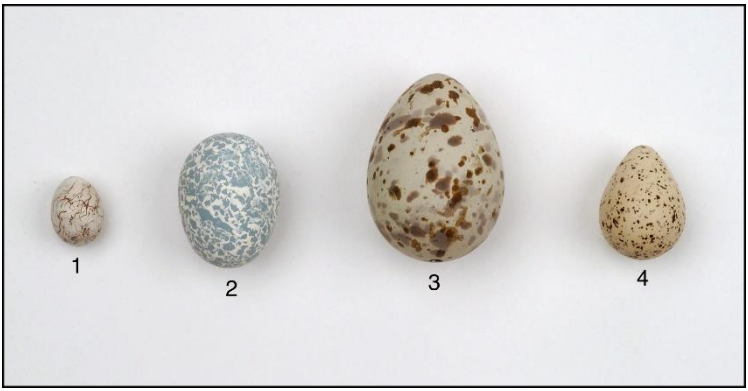
The eggs with the reddest colours belong to the genus of Bush-Warblers, one of which is the Cetti's Warbler. The most vivid greenish eggshell colours are produced by the Elegant-crested Tinamou. These South-American birds have already been mentioned as laying conspicuously coloured eggs. A typical representative of a bird laying blue eggs is the American Robin.

Readers who are interested to see such coloured eggs in reality can best be referred to egg collections. The largest bird egg collections in the world belong to the British Natural History Museum in Tring, England and to the Western Foundation of Vertebrate Zoology in Camarillo CA, USA. Both institutions claim to have more than one million eggs, representing 4,000 (Western Foundation) or more (British Museum) bird species. These two egg collections are by far the largest in the world. It is estimated that less than 10 other collections comprise more than 100,000 eggs. But quite a number of major museums have holdings of about 50,000 eggs. Unfortunately, such collections are very rarely open to the public, and if so, only a small part of the collection is shown. Therefore, this booklet tries to be a substitute for something which cannot be easily seen either in a museum or in nature.

Colour patches illustrating further bird's eggs with bright or deeply saturated eggshell colours.

A further criterion adding to the different appearance of avian eggs is the size and shape of shell patterns. There may be spots, stains, streaks or hair-like structures. The Yellowhammer, for instance, has eggs with a threadlike structure, looking like a scribble.

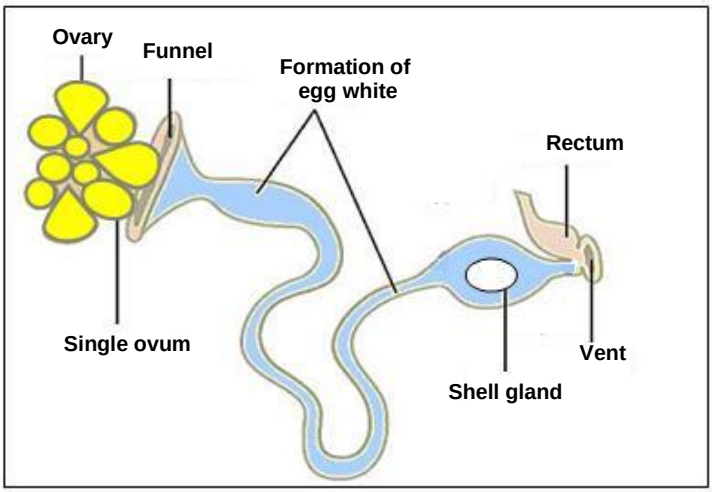
It is interesting to note that shell patterns occur only with the red-brown pigment. Therefore, spotted eggs are always red-brown, while the bluish-green pigment leads to a uniform coloration. Another observation is that the red-brown coloration of freshly laid eggs can be removed by washing, whereas the green coloration is resistant.



Eggs with different patterns: (1) threadlike (Yellowhammer), (2) covered with a reticulate layer of limestone (Guira Cuckoo), (3) large spots (Kittiwake), (4) fine dots (Ringed Plover)

How pigmentation is added to the shell

The eggshell consists of layers, starting externally with a chalky shell layer followed by an outer and an inner membrane. The surface layer contains the pigments responsible for the coloration of the egg. The strength of the coloration depends on the amount of pigments. Only three pigments produce the entirety of eggshell colours: One is protoporphyrin, producing a red-brown coloration, often in form of spots or stains. The second pigment is biliverdin, responsible for the bluish green shades. Biliverdin is a degradation product of the red blood pigment hemoglobin, while protoporphyrin is a compound used for the synthesis of hemoglobin. The conversion of the red blood pigment to biliverdin can also be observed on the human skin, when the colour of a bruise turns from red-blue to greenish blue. The third pigment is a combination between Zinc and biliverdin, producing green-yellow colour shades. The ratio between the three pigments determines the hue and saturation of the resulting colours.

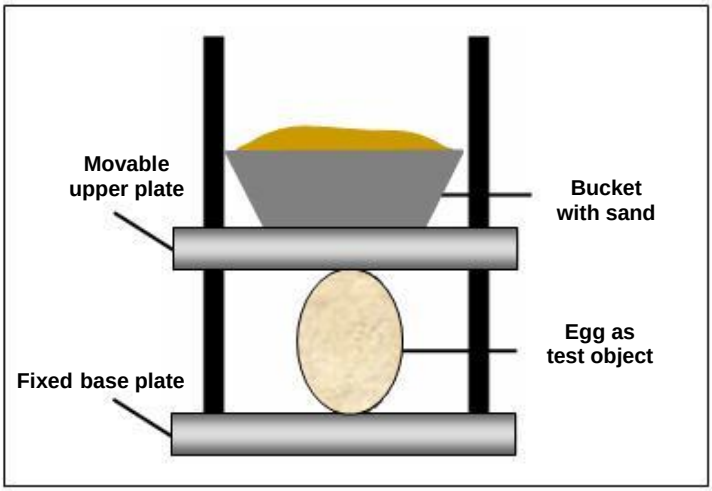


Formation of egg in the oviduct of a hen

The process of egg pigmentation can best be seen when looking at the oviduct of a hen (see figure): From the ovary, a single ovum (the pre-stage of the yolk) moves through the funnel down to the oviduct. Then the ovum will be coated with the egg white and the inner and outer membrane. Next, the egg travels to the shell glands, where the calcification of the shell begins. This is also the place where some bird species have glands in the oviduct wall to add pigments to the shell. The green-blue pigment is deposited first, resulting in a uniform coloration. The red-brown pigment added later produces either a uniform coloration or spots, if the egg remains still. If the egg is moving or rotating, lines or streaks appear. The amount of pigments added to the shell is largely controlled genetically. The egg spends approximately 20 hours in this part of the oviduct and acquires its colour during the last 3 hours. Finally, the pigmented egg is expelled through the vent. Altogether, it takes about 25 hours for the egg to travel down the oviduct.

The egg as a unique package

There is a saying "as fragile as eggs". However, people handling eggs every day know that the eggshell is not synonymous with fragility. The eggshell strength is well investigated in the case of hens' eggs, as they are a commercial product. The figure below shows a device that tests the eggshell strength: The egg is placed between two plates, the upper being movable. A bucket resting on top of the upper plate is being filled with sand until the egg breaks. The combined weight of the sand, the bucket and the mobile plate can be used as a value for the force needed to crush the egg.



Device to test the stability of eggs

A typical value to break an average hen egg is 3.5 kg, roughly equivalent to the weight of a brick. An interesting fact is that if an egg is positioned laterally (lying on the side) and crushed under the same conditions, lower values result, typically around 2.8 kg. At any rate, it can be said again that no two

eggs are alike, because the values for the crushing force may vary within a larger interval.

The high stability of eggs is even more remarkable if it is taken into account that the eggshell possesses tiny pores to enable the unborn animal to breathe. The domestic hen egg has around 10,000 pores permitting the exchange of respiratory gases (oxygen and carbon dioxide). However, the stability of the eggshell must not be too high, because the chick must still be able to escape from the shell. In order to do this, chicks have a so-called egg tooth allowing them to make an initial break into the shell. This is facilitated by the fact that the inside of the eggshell is easier to crack than the outside. The egg tooth is lost shortly after hatching. The stability of the eggshell is primarily determined by its thickness. Chicken eggs have a thickness of 0.30 to 0.36 mm, corresponding to three sheets of paper used for this booklet. The thinnest eggshells belong to hummingbirds with a thickness of 0.03 mm. This is thinner than any paper. At the other end of the scale is the Ostrich egg, which has a shell thickness of 2.25 mm. This eggshell is too thick to be cracked by an egg tooth. Ostrich chicks develop a hatching muscle in the neck, which, when stiffened, can be used together with the legs to work their way out of the shell.

It makes sense that eggs of large birds have a thicker eggshell than those of small birds because the egg must be able to support the weight of the incubating bird. In addition, it is important that the laying bird dispose of an adequate amount of calcium for the shell production. If this calcium metabolism is malfunctioning, for instance because of environmental pollutants, the reproduction may be endangered. Exactly this happened when DDT, a synthetic pesticide, was introduced in 1944 for pest control. Less than 10 years after its first application, it was reported that DDT is responsible for a higher mortality of many bird species. What happened was that birds

consuming DDT-contaminated prey produced eggs with a thinner shell that often broke before hatching. Although DDT was extensively sprayed in the US by airplanes, the dangers of DDT became not known until the national symbol, the Bald Eagle, was threatened with extinction. When DDT was banned in 1972, there were fewer than 480 nesting pairs. However, the Bald Eagle and other endangered bird populations started to recover quickly thereafter.

The function of egg colour and patterning

Birds have no influence on their egg coloration or patterning, nor do they even know in advance how their eggs appear. Therefore, it is a misconception that birds can consciously camouflage their eggs to protect them against predators. Equally, the Cuckoo is unable to deliberately produce eggs that mimic the host egg. In both cases, the colour and patterning of eggshells is the result of an evolutionary process that happened in millions of years. It is assumed that, at the beginning of the evolution, all birds' eggs were white, similar to reptiles and amphibians, which still lay white eggs today. For birds nesting in holes (as wood-peckers and owls) or for birds keeping their nests covered (as pigeons), there was no need to protect the eggs by camouflage against predators. Therefore, these eggs are still white. In contrast, eggs that are laid on the ground or in open nests, need coloured or patterned shells to make them less visible to potential predators. In the course of evolution, some birds have developed perfectly camouflaged eggs for their habitat. In cases this has happened to a lesser extent, it is assumed that the eggs are not equally palatable for predators. It is even suspected that the opposite of a camouflaged egg, namely a conspicuous egg, may deter a predator. (This phenomenon is called *aposematism*.) This is a possible explanation for the existence of the strongly coloured and glossy eggs of certain tinamous.

A further function of egg colour is to protect the clutch against nest parasites. One example is the before-mentioned Cuckoo. However, evolution of egg appearance has created a situation where parasitic eggs and host eggs look often almost identical (apart from the egg size), meaning that this evolutionary competition between parasites and hosts has currently no winner. But to secure their own reproduction, the female parasite has to lay more eggs per year than the host bird.

Eggs of the Common Murre with different coloration and patterns

In some species, such as the Common Murre, each female lays eggs with very different markings. This uniqueness has a purpose: As these birds nest in large colonies on cliffs, the individual colour pattern helps the parent birds to identify their own eggs when they are leaving the hatching site for feeding.

A further function that can be attributed to the egg colour is a heating effect, which can be either wanted or unwanted. It is well known that a coloured object absorbs more heat when the colour is darker. (In bright sun light, the heat in a black car is higher than in a white car.) Measurements showed that, in

direct sun light, the yolk temperature of a brown egg can be about 3 ºC higher than of a white egg. Therefore, if coloured eggs are exposed to direct sun light, such as in Africa, there is a danger of fatal overheating of the embryo. This is the reason why Ostrich eggs are still white, despite the fact that their eggs are unattended for up to 30 hours between deposing the first and the last egg and thus being exposed to predators. In the European climate, however, an additional heat effect caused by a darker eggshell colour may sometimes be beneficial.

Appendix: How to become an egg collector

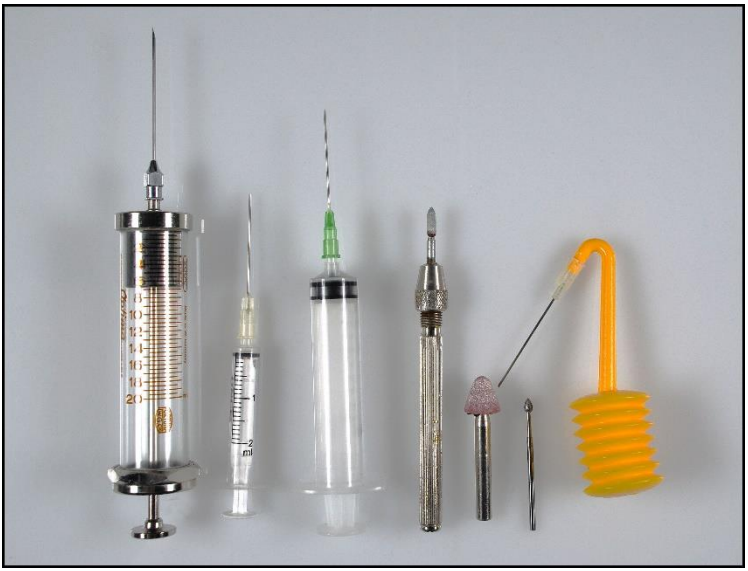
Egg collecting is not really expensive, as there are no stores or institutions selling birds' eggs for collectors. To find the first eggs for a potential collection, it is recommended to visit a so-called "Easter Market" where empty eggshells are offered for artists who paint or decorate eggs. Usually, these eggshells originate from chickens, geese, quails, pheasants or ostriches. A more attractive source for egg collectors are bird breeders. They are used to giving away unfertilized eggs, as they are worthless for the purpose of breeding. There are professional breeding stations, for instance for parrots or birds of prey, and hobby breeders, for instance for songbirds. A collector must be prepared to spend a considerable amount of time and patience to find breeders who are willing to make a contribution to his collection. It is even more difficult for a "small egg collector" to obtain unfertilized eggs from zoos and bird parks, although birds are bred there on a large scale. Such institutions are known to exchange their eggs only amongst themselves or give them to museums at best. Of course, there are exceptions, for instance if one knows a curator or a bird keeper. Eventually, an egg collector may meet another collector, which can be the beginning of an exchange activity. And under lucky circumstances, a collector has the chance to take over a collection or parts of it. What an egg collector should never do is take an egg from a nest that is incubated. It is true that if an egg is taken, the incubating bird completes the clutch with a new egg. But a collector should refrain from doing so, since the bird is already forced to do this when a predator takes an egg. It may happen, however, that an abandoned nest with eggs is found.

This leads to the question whether or not egg collecting is legal, or in other words, whether the possession of eggs is legal. Until the early 1900s, this issue was never debated. But

from this time on, a growing number of international treaties and national laws have been enacted to protect birds including their nests and eggs. In most countries, the possession of eggs originating from wild birds is nowadays illegal. But eggs from wild birds that have been collected before a national law has been introduced, are considered to be in legal possession. An egg collector can be forced anytime to show that the eggs in his possession were "lawfully" obtained. Lawful means that the eggs are laid by birds in captivity. It is also regarded as lawful to have eggs from abandoned nests or from nests located on an estate owned by the collector. Many collectors are only interested in complete clutches. It can be difficult, if not impossible, to provide evidence that those clutches always originate from abandoned nests. Therefore, egg collections based mainly on complete clutches are bound to raise the question whether they are lawfully acquired. When collecting single eggs, however, it is easier to attest that the eggs originate from birds living in captivity. Many collectors devote their life to the pursuit of egg clutches. This is illustrated by an exemplary motion picture entitled "A breed apart", which was released in 1984. In this story, a bold climber is hired by an obsessed egg collector to steal eggs from a nest of the Bald Eagle, the national heraldic bird of the US. Today, eggs of the Bald Eagle can be obtained more easily from breeders of birds of prey. One bird, however, whose eggs are significant for each collection, never breeds in captivity: It is the cuckoo, of which 15 species exist (all belonging to the genus of *Cuculus*). Cuckoo eggs can only be found in nests of their host birds, and legally they must come from abandoned nests. Therefore, cuckoo eggs are more difficult to acquire than eggs of birds of prey living in breeding stations.

A very significant international regulation for egg collectors is the *Convention on International Trade in Endangered Species of Wild Fauna and Flora*, known as *CITES*, or also known as

the *Washington Agreement*. The Convention entered into force in 1975 and has been signed by 172 countries to this day. The main objective of CITES is "to ensure that international trade in specimens of wild animals and plants does not threaten their survival". Objects falling under this convention are also eggs as product of wild living birds. However, not all birds are subject to this convention. Three appendices distinguishing the degree of threat comprise some 1,500 (of total 10,000) bird species, among them complete families as the birds of prey, the parrots and the hummingbirds. If birds' eggs of these species are intended to be imported in a member country of CITES, a permit (a so-called CITES certificate) is required, giving evidence that the eggs origin from captive birds.



Tools to remove the egg content: Syringes of different volume, drills with different heads and a so-called egg-pump

An egg collector has to make sure that his eggs do not rot. For this purpose, the yolk and the egg-white have to be removed.

This is only possible if the content is sufficiently liquid, i.e. in the case of freshly laid eggs. If the collector obtains old eggs, the content is usually difficult to remove what raises the question whether the egg should be disposed. If the eggshell is completely intact, the egg may be added to the collection. However, the danger is that due to a leakage, microorganisms can deteriorate other eggs. In order to remove the egg content, a circular hole is made with a small drill. Basically, one hole drilled in the side or in the end is sufficient. The content is not blown out, because this would require two holes. It is removed by using a syringe or a so-called egg-pump. The needle and the hole on the eggshell need to have a diameter that allows sucking out the slightly viscous content easily. Once the eggshell is empty, tap water is poured in for rinsing. In the next step, soap water or vinegar is used for rinsing. As a final step, the eggshell is treated with a germ-killing agent. An inexpensive solution is formalin (37% formaldehyde in water) applied in a dilution of 1:10 (one part formalin in 10 parts water). When injected into the egg, the solution should be allowed to react for a couple of hours. Subsequent rinsing is not necessary.