Incredible, edible eggs

Model 1. Any egg is a type of *cell* that is specialized for *sexual reproduction* – the process by which two parents contribute genetic material (*genes*) to make a new individual. *Germ cells* (e.g. egg and sperm) contain *half* the genetic material necessary to make an individual – the cells are *haploid*. Only eukaryotic organisms undergo *sexual reproduction*, and not even *all* eukaryotic organisms….only the most complex.

Of the two reproductive *germ cells* that combine their genetic material (*genes*) to make a new individual, the *egg* is the larger, less mobile one. The *egg* cell receives the *sperm cell* (the carrier of the other half of the genetic material), accommodates the joining of the two *haploid* sets of *genetic material*, and subsequently divides and differentiates into the new embryonic organism.

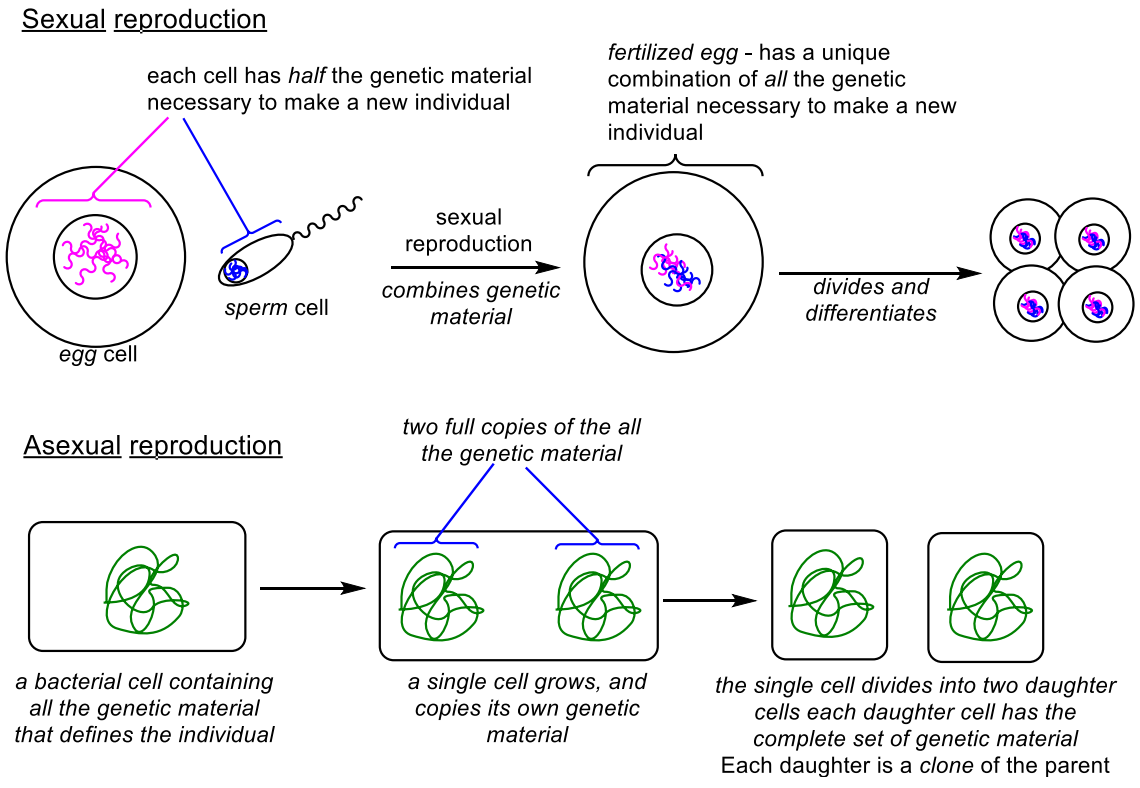


Figure 25.1. A comparison between sexual and asexual reproduction

Asexual reproduction is how bacteria, yeast and other simple organisms multiply. By definition, the product cells of *asexual reproduction* are exactly genetically identical to the single, original parent – the daughter cells are *clones* of the parent. On the other hand, sexual reproduction combines two sets of genetic material into a new, unique individual.

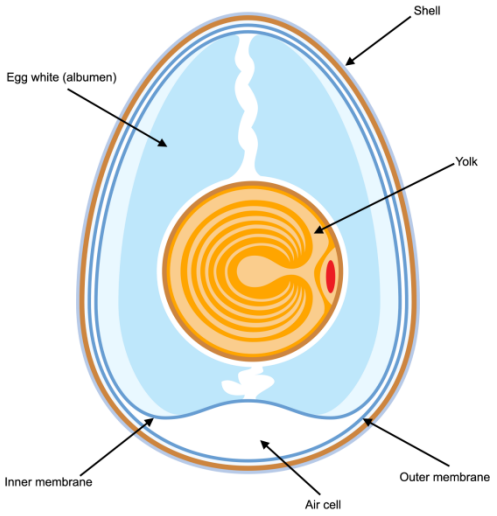


Figure 25.2. Diagram of a chicken egg (image licensed under Creative commons)

The familiar chicken egg has a *yolk* surrounded by egg *white*, contained within a hard shell.

- The Yolk: accounts for ~ ⅓rd of the weight of an intact chicken egg. Comprised of mostly fats and proteins – it carries 75% of the calories and most of the iron, thiamin and vitamin A. Its purpose is to provide food for a developing chick[2].
- The White: accounts for ~ ⅔rd of the weight of an intact chicken egg. It is 90% water – the rest being protein. There are only traces of minerals, fatty material, glucose (a sugar) and vitamins. The white provides essential proteins and water, and also provides protection to a developing chick[2].
- The shell: Made of calcium carbonate and protein, the shell is riddled with pores (tiny holes) that allow gases to pass in and out of the egg.

Table 25.1. The Composition of a U.S. Large Egg[2]

	Whole Egg	Egg White	Egg Yolk
Weight	55 grams (g)	38 g	17 g
Protein	6.6 g	3.9 g	2.7 g
Carbohydrate	0.6 g	0.3 g	0.3 g
Fat	6 g	0	6 g
Monounsaturated	2.5 g	0	2.5 g
Polyunsaturated	0.7 g	0	0.7 g
Saturated	2 g	0	2 g
Cholesterol	225 milligrams (mg)	0	225 mg
Sodium	71 mg	62 mg	9 mg
Calories	84	20	64

Chicken eggs are created by the female hens. The hen will produce the eggs whether they are fertilized or not – mass produced, grocery-store eggs are *not* fertilized. There is no nutritional difference or noticeable difference in physical appearance between

fertilized and unfertilized chicken eggs[1]. A chicken will lay eggs (fertilized or not) until she has accumulated a certain number of eggs in her nest. If the eggs are removed – perhaps by a predator…or a human – the hen will lay another to replace it, and may do so indefinitely[2].

Eggs are unmatched as a balanced source of amino acids, and they include a plentiful supply of alpha linolenic acid – an essential, polyunsaturated, omega-3 fatty acid – as well as several minerals and most vitamins. An egg contains everything you need to make a chick[2]. Eggs also contain *cholesterol* - a *hydrophobic* molecule. Cholesterol is also considered a *lipid* because fatty acids can be converted into cholesterol using many *enzymes*. In humans, high blood cholesterol does increase the risk of heart disease – a fact that has long made medical professional recommend limiting egg yolk consumption to 2-3 per week. However, recent studies show egg consumption has little effect on blood cholesterol, rather *saturated fats* have a far more powerful effect on raising blood cholesterol. In addition, the *phospholipids* in eggs yolk interfere with our ability to absorb the cholesterol…so we don't have to count our eggs after all.

Questions:

1. In Figure 25.1, why are the egg, sperm cell and fertilized egg(s) represented with their genetic material inside another circle? Why is this second "inside" circle absent in the bacterial cell in the lower part of Figure 25.1?

2. The chicken egg found in the grocery store contains which of the cells in Figure 25.1? Explain.

[1] Folklore indicates that a "blood spot" in an egg indicates fertilization. This is incorrect. The blood comes from the rupture of a blood vessel during formation of the egg and has nothing to do with fertilization. Blood spots are not harmful nor do they affect taste. They can simply be removed with a spoon.
[2] On Food and Cooking, by Harold McGee, 2004, Scribner.

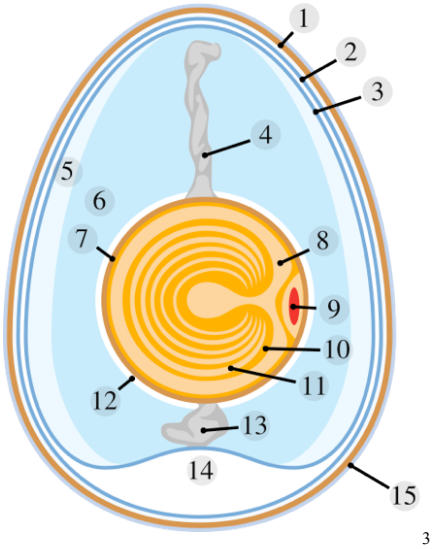
3. Does a chicken egg contain genetic material? Is it *haploid*? Explain.

4. Egg whites are often recommended as an excellent source of protein in the human diet. Now, egg white contains about 60% of the protein in the egg, while egg yolk contains the other 40%. Why are egg whites (vs. yolks) such a "good" (i.e. high quality) source of protein?

5. It is known that excessive consumption of saturated fat is known to raise blood cholesterol and contribute to heart disease. Eggs contain saturated fat…so why might normal egg consumption not have a measurable effect on blood cholesterol levels in humans.

Inside an Egg

Model 2.



[3]

1. Eggshell – hard calcium carbonate and protein
2. Outer membrane - antimicrobial protein layer
3. Inner membrane – antimicrobial protein layer
4. Chalaza – protein cord that anchors yolk
5. Exterior albumen (outer thin albumen, less protein)
6. Middle albumen (inner thick albumen, more protein)
7. Yolk membrane – surrounds and protects yolk
8. Primordial white yolk: the first yolk to surround the germ cell
9. Germ cell (i.e. the egg cell) – *not actually red in real life*
10. Yellow yolk – fats and protein for germ cell
11. White yolk – less dense, high in iron
12. Internal albumen – the coating from which the chalazae extend
25. Chalaza - protein cord that anchors yolk
14. Air cell – air for chick to breathe
15. Cuticle - protein coating that gives egg color and blocks entry of bacteria

Figure 25.3. Detailed anatomy of a chicken egg

The Yolk: The *yolk* (10, 11) surrounds the *germ cell* (9). The *germ cell* contains half the genetic material needed to make a chick. This *germ cell* is the *haploid egg cell.* The germ cell is surrounded by *white (or light) yolk* (11) and *yellow (or dark) yolk* (10).

Table 25.2 The Proteins in Egg White Albumen[4]

Protein	*% of total*	*Natural Function*
Ovalbumin	54	Nourishment for chick, *may* block digestive enzymes
Ovotransferrin	12	Binds iron
Ovomucoid	11	Blocks digestive enzymes
Globulins	8	Plug defects in membranes and shell
Lysozyme	3.5	Enzyme that digests bacterial cell walls
Ovomucin	1.5	Thickens albumen, inhibits viruses
Avidin	0.06	Binds the vitamin biotin
Others	10	Bind vitamins; block digestive enzymes….

[3] Image licensed under creative commons.
[4] On Food and Cooking by Harold McGee, 2004, Scribner

The white yolk is less dense and especially rich in iron, while the yellow yolk is denser and rich in fats and proteins. The color of the yellow yolk depends on what the hen eats….the pigments in her food. The yolk is much larger than the *germ cell*. The yolk membrane (7) surrounds and protects the yolk and indicates egg freshness.

The White: The egg white is made of mostly water and a mixture of proteins called *albumen* (5,6,12). The *albumen* not only nourishes the chick, it is a biochemical shield against infection and predators. The *chalazae* (4,25) are dense elastic cords made of *albumen* that anchor the yolk to the ends of the shell and allow it to rotate while suspended in the middle of the egg. *Chalazae* are visible in a raw egg when it is cracked open.

Membranes and shell: The *membranes* (2,3) line the inside of the shell and are made of antimicrobial proteins. The *shell* (1) is made of calcium carbonate and protein, and since the developing chick would need to breathe, the shell has thousands of tiny *pores* or holes. These *pores* are invisible to the eye. The *cuticle* (15) is a thin protein coating on the shell. This coating initially blocks the pores to slow the loss of water and prevent the entry of bacteria. When the chicken deposits the proteinaceous *cuticle*, pigment molecules are also deposited into the shell and give the egg its color. The pigments deposited are dependent on the type of chicken. White, brown, even blue eggs and yellow spotted eggs – all the colors have to do with the genetic makeup (the breed) of chicken, for example Rhode Island Reds lay brown eggs. There is no nutritional difference between white, brown….or even blue eggs. The *air cell* (14) provides the developing chick with its first breaths of air and is also an indicator of egg freshness.

Questions:

6. Is a chicken egg made of single cell, many cells, or neither? Explain.

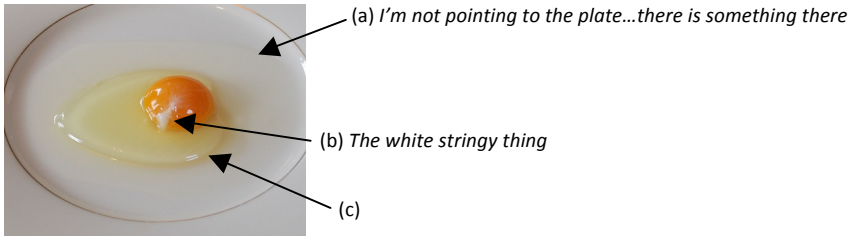
7. A friend tells you that brown eggs are organic because they come from a small farms and "free-range" hens. (i.e. they aren't mass produced like typical grocery-store eggs).
    a. Is a brown egg necessarily "organic"?
    b. Does a brown egg necessarily come from a "free-range" hen?
    c. How is a white egg different from a brown egg?

8. When an egg is hardboiled, there is a persistent bit of uncoagulated yolk at the center if the hard cooked egg.
    a. What is at the *very center* of the yolk?
    b. Is your answer to (a) consistent with the fact that very high concentration of iron prevents yolk from "setting" or coagulating?

9. In Table 25.2 we see that egg white proteins mostly *bind* stuff. Only one is called an *enzyme*, what makes an *enzyme* different?

10. Explain why chicken egg white protein could be considered a *mixture*. Include Table 25.2 in your answer.

11. Identify the labeled components of the photo below:



Model 3. Although an egg can remain edible for weeks if keep intact and cool, egg quality does deteriorate over time. When an egg is freshly laid, it contains carbon dioxide *dissolved* in the white and yolk. When carbon dioxide is *dissolved* in water (and egg white is 90% water) it is in the form *carbonic acid*. When acids are dissolved in water, they make the water *acidic*.

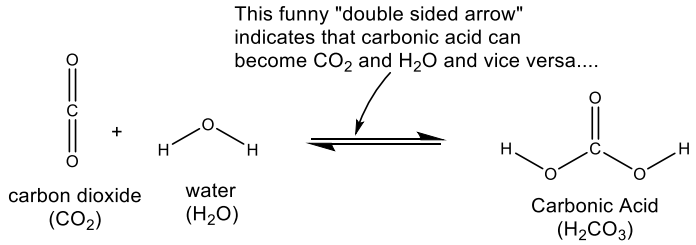


Figure 25.4. Carbon dioxide in water makes carbonic acid

This can be measured by something called a pH scale. On a pH scale, 7 is neutral pH, below 7 is *acidic* and above 7 is *alkaline*. The more acid in the water, the lower the pH, while adding acid to an *alkaline* solution will lower the pH.[5]

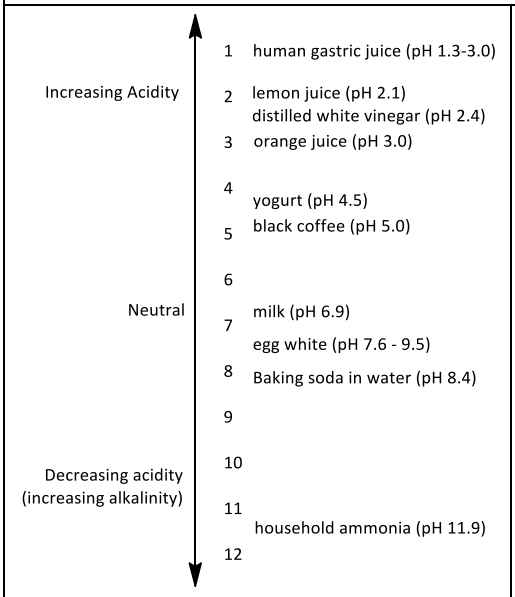


Figure 25.5. pH scale, a measure of acidity and alkalinity

As eggs age, the carbon dioxide dissolved in the white and yolk gradually escapes through the pores in the shell. As carbon dioxide leaves the egg, the white and yolk become more *alkaline.* This change in pH changes interactions between egg white *albumen* proteins (the proteins interact less) and the *egg white albumen* (5,6) is consequently runnier.

In addition to carbon dioxide escaping through the pores of the shell, water molecules also escape – making the overall contents of the egg shrink. This shrinking allows air to travel in through the pores in the shell and enlarge the air cell. In a typical refrigerator an egg will lose 4 milligrams of water a day.

A final indicator of egg freshness is the *yolk membrane* (7). Because the yolk contains less water than the white, water gradually crosses the membrane from the white into the yolk. In the refrigerator, the yolk gains about 5 milligrams of water per day. This increase in water makes the yolk swell (enlarge) and the yolk membrane weaken.

[5] For a full lesson on pH, see Activity 8

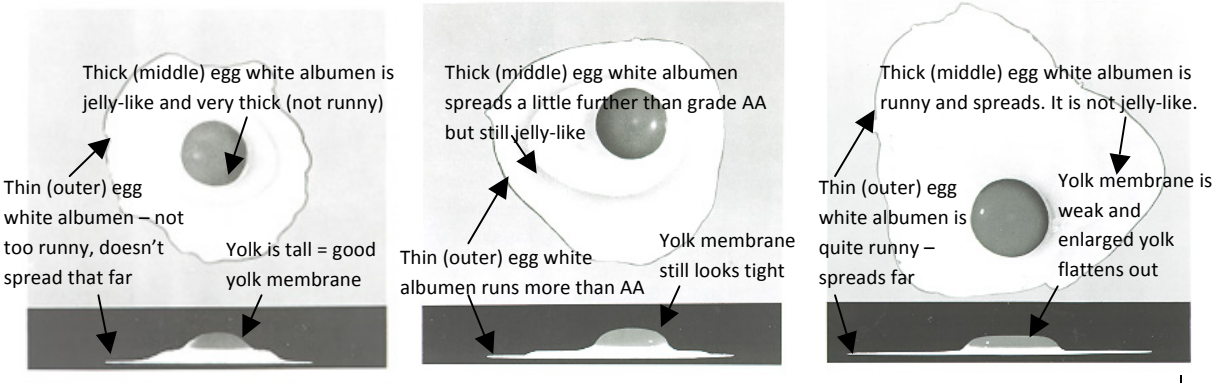


Figure 25.6. Egg grade is a function of egg white and yolk membrane[6].

12. Explain why the egg white is more *alkaline* after carbon dioxide *escapes* from the egg white and out the shell (through the pores).

13. Around 1750, English cookbook author Hannah Glasse noticed that fresh eggs quickly sank in a bowl of water, while old eggs bobbed and really old (probably rotten) eggs floated in the water. A floating egg must have a large quantity of air inside the shell to make it less dense. What factors about egg anatomy and chemistry explain this simple "home test" for egg freshness?

14. Given the qualities that affect egg freshness (and consequently egg quality), is a grade AA egg any more or less nutritionally valuable that a grade B egg. That is, have the amounts of protein, fat etc changed between the two grades of egg? Explain.

[6] United States Standards, Grades, and Weight Classes for Shell Eggs AMS 56 and the Home and Garden Bulletin number 264, US Department of Agriculture, Agriculture Marketing Service. Public Domain.

Putting it all together:

15. Due to the public desire for cholesterol-free and lower fat eggs, food manufacturers have come up with substitutes (e.g. egg beaters) that imitate whole beaten eggs – these substitutes can be scrambled (for scrambled eggs or omelets) and can be used in baking. These substitutes consist of genuine egg whites mixed with an imitation yolk.
    a. Why are the whites genuine, but the yolks imitation?
    b. Based on your knowledge of egg yolk composition and what the consumer wants, what molecules might food manufacturers include in an imitation egg yolk?

16. You find some eggs that your roommate bought in the refrigerator. They aren't in their original carton, so you don't know the expiration date. Knowing that eggs have a good shelf life in the refrigerator and since your roommate has left for the weekend, you decide to make yourself fried eggs for breakfast. You crack the egg gently and notice the yolk breaks immediately upon hitting the warm pan - this gives you a clue to the quality (or grade) of the egg and some insight into its age. Explain.

17. Before we had modern refrigeration and shipping methods, it used to take eggs longer to get to market. Egg producers would wash the eggs with soap and water to remove bacteria, then coat the eggs in mineral oil. Without the mineral oil, the eggs would spoil very rapidly. What did the washing remove that made the eggs go bad so much more quickly?

18. *Ovalbumin* is the most abundant protein in eggs and the protein most likely to cause egg allergy in humans. Since developing an allergy requires exposure to the allergen (e.g. ovalbumin), medical professionals recommend that babies not eat egg white until after they are one year old, and yet it is considered perfectly safe for babies to eat egg yolk. Why?