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HUMAN HEALTH
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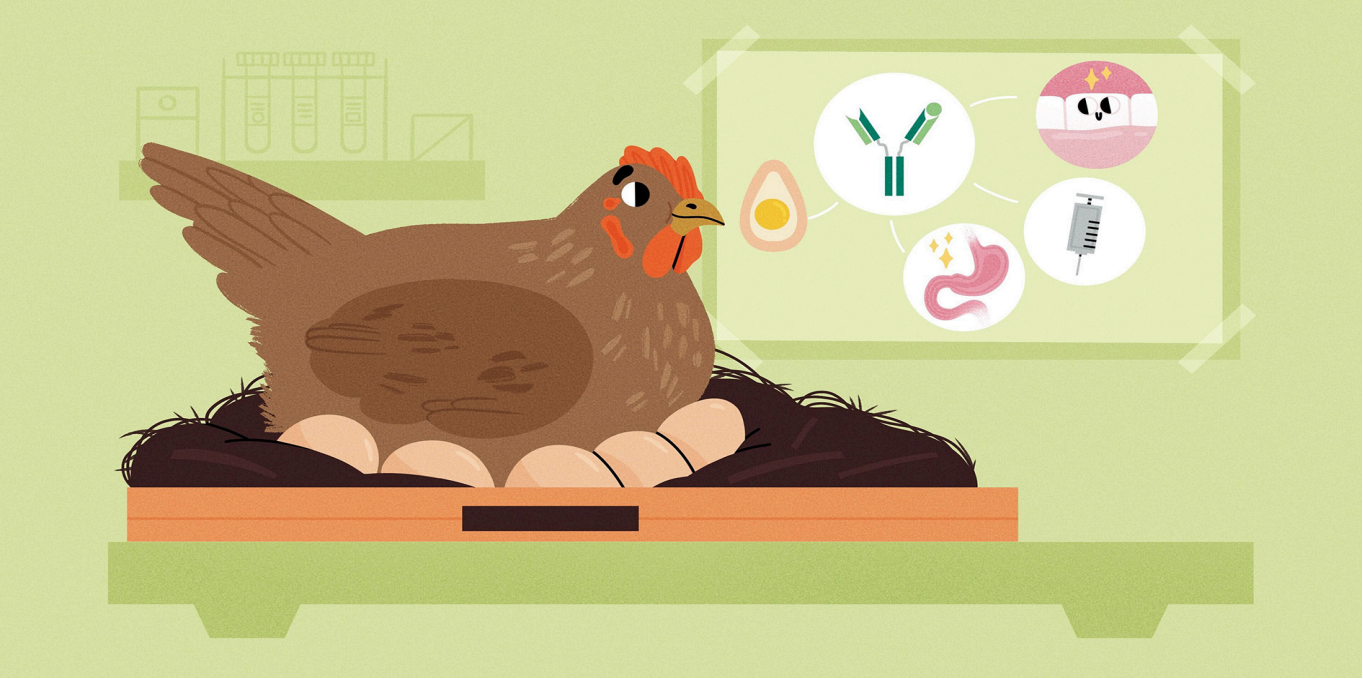

ANTIBODIES FROM HEN EGGS FOR HUMAN HEALTHCARE

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YOUNG REVIEWERS:


ERIN
AGE: 9


HARRISON
AGE: 12


JACK
AGE: 16


PABLO
AGE: 15

The blood of almost all animals contains proteins known as antibodies. The types of antibodies differ from one animal to another, but the main purpose of all antibodies is to prevent animals from getting sick. Antibodies help animals to protect themselves against bacteria, viruses, and other dangerous invaders. Scientists have found a way to obtain antibodies from some animals and use them to improve human health. Antibodies from hens are especially promising because large quantities of hen antibodies, known as IgY, can be obtained from their eggs—a process that does not hurt the birds at all. IgY is a very stable antibody that has been used to treat human diseases like dental cavities and stomach ulcers. Soon, we may even have an IgY that can treat or prevent COVID-19 and other viral pandemics. Therefore, IgY is a very valuable resource that will continue to improve human healthcare.

INTRODUCTION

Hens—female chickens—are domestic birds that we are all familiar with. Their meat and eggs provide much of the protein needed to prevent hunger all over the world. Beyond this traditional purpose, hens have another hidden treasure—a protein known as IgY. IgY is a type of **antibody**—an important component of the immune system. To understand IgY and appreciate its power, we will first delve into what antibodies are.

ANTIBODY

A type of protein that helps the body fight foreign invaders.

WHAT ARE ANTIBODIES AND WHY ARE THEY IMPORTANT?

Antibodies are a special type of proteins found in the blood. They are part of the body's **immune system**—its defense system against dangerous invaders like bacteria and viruses. Most antibodies are made from four proteins bound together. Two of the proteins are longer and are called heavy chains, while the other two shorter chains are called light chains. These four chains are linked to each other to form the three-dimensional structure of the antibody molecule, which resembles the letter Y (Figure 1).

IMMUNE SYSTEM

A group of cells, and the substances they produce, that together help the body stay healthy by fighting off germs like viruses and bacteria.

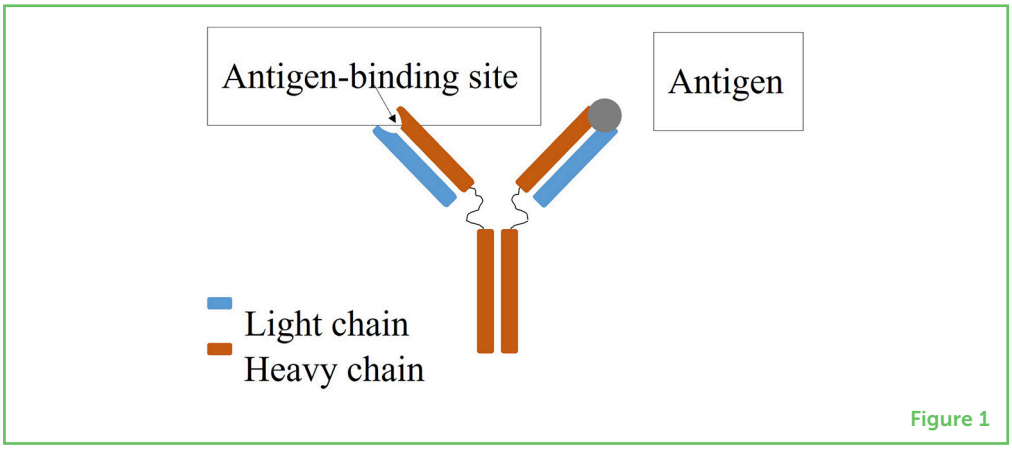

Figure 1

Antibodies are important molecules in the immune system of humans and other animals. Most antibodies have a Y-shaped structure and are made of two "heavy" protein chains (orange) and two "light" chains (blue). The tips of each arm of the Y contain regions unique to each antibody molecule. These are the parts of the antibody that bind to a piece of a foreign invader, like a virus or bacterium. Such pieces are called antigens, and thus the tips of the Y are called antigen-binding sites.

Have you ever wondered why your parents take you to the doctor for **immunizations** ("shots"), even though you are healthy? Immunizations protect us from germs such as viruses that we may encounter in the future. Immunizations contain harmless components of the viruses, bacteria, or other germs. When we are immunized, these components "teach" the body to react in case we encounter the dangerous form of the germ in the future. An informed immune system is always on the lookout for alien substances that may harm us, and it is ready to produce antibodies to help our bodies fight off these invaders.

IMMUNIZATION

The act of giving a person or animal a non-harmful component of an infectious organism to protect the person/animal from harmful infection with that organism in the future.

ANTIBODIES RECOGNIZE ANTIGENS

ANTIGEN

A substance that can cause the body to produce antibodies. Examples of antigens are viral proteins and pollen from plants.

ANTIGEN-BINDING SITE

If an antibody is seen as a lock, and the antigen as a key, the antigen-biding site would be the keyhole where the key fits.

Antibodies recognize a tiny part of a germ, called an **antigen**, and they initiate a response by the rest of the immune system that will kill the germ. Antibodies are produced by cells of the immune system called B cells. B cells can "remember" an encounter with a germ and, if the body encounters the same germ again, the B cells will quickly start producing antibodies [1].

The ability of antibodies to recognize antigens comes from the tips of the "Y," called the **antigen-binding sites** of the antibodies (Figure 1) [2]. All the antibodies produced by one B cell are the same, but they have different antigen-binding sites than the antibodies produced by any other B cell. This means that each B cell produces antibodies that can identify only one antigen. In the body, there are millions of B cells and thus millions of different kinds of antibodies. Chances are there is at least one antibody in the body that will recognize just about any type of dangerous invader that comes along. These antibodies include those generated against germs we encountered when were just babies.

MOST ANIMALS HAVE ANTIBODIES

All vertebrates—including fishes, amphibians, reptiles, birds, and mammals—produce antibodies. Each vertebrate has slightly different types (called classes) of antibodies in its body (Figure 2). The names of antibody classes are shortened using the abbreviation Ig (for immunoglobulin, another word for antibody) followed by a letter of the alphabet. Mammals (including humans) have five classes of antibodies: IgA, IgD, IgE, IgG, and IgM. IgG is the main antibody released during the immune response in mammals. IgF and IgX are classes of antibodies found in amphibians, while IgZ is found in fishes [3]. In birds, the main antibody class is IgY. Both IgG and IgY have similar "Y"-shaped structures, but with some notable differences that make the IgY structure more stable than IgG.

MEET THE HEROES: PRODUCTION OF ANTIBODIES IN ANIMALS FOR HUMAN USE

Using the principles of immunization discussed earlier, scientists can instruct the immune systems of many animals to produce antibodies against whichever antigens they choose. For example, a scientist can immunize an animal with a piece of a virus and that animal will generate antibodies against the virus. But the purpose of generating antibodies this way is not to use them to protect the immunized organism—it is to use them to protect *another* organism—humans.

Figure 2

All vertebrates make antibodies, but the classes (types) of antibodies vary across animals. IgM was the first class of antibodies to evolve, and it is only found in certain fishes. IgG evolved the most recently and is the most advanced antibody. IgG is the main antibody in almost all mammals, including humans. IgY is the main antibody in all birds and some reptiles (Image derived from: https://www.51yuansu.com/).

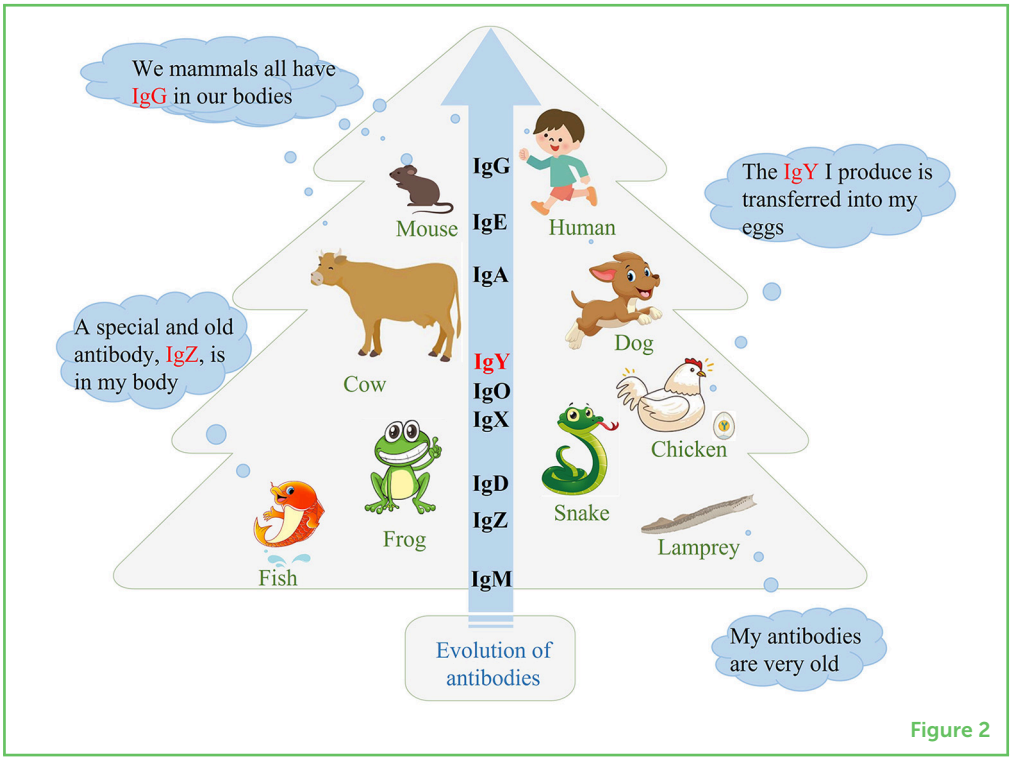

Figure 2

SERUM

The liquid part of the blood that surrounds the blood cells.

Antibodies are generally found in the liquid part of the blood, which is called the **serum**. In birds, IgY can also be found in egg yolks. Any animal that produces antibodies could be used by scientists to produce antibodies for use in humans. However, imagine having to obtain the blood of a polar bear or a tiger shark! For practical reasons, only a handful of animals are used to generate the antibodies used in medicine: mice, rats, rabbits, goats, sheep, horses, and hens. Each of these organisms has its advantages and disadvantages. For example, rodents like rats and mice are easy to handle but do not have much blood; while bigger animals like sheep and horses are more difficult to handle, but larger amounts of blood can be taken from them.

Scientists worry about the pain animals might feel when their blood is drawn. Recently, there is a growing push from scientists and the public to protect research animals. A plan called the 3Rs has been developed, with the Rs being: *R*educe the number of animals used, *R*efine experiments so that they cause the least possible suffering to animals, and *R*eplace animals with other methods [for more information on improving animal welfare by reducing (Tremoleda, 2022), refining (Jirkof, 2022), and replacing (Hartung, 2022), see the linked Frontiers for Young Minds articles. Here is where hens save the day!].

WHY HENS ARE THE BEST

Like all birds, hens lay eggs. After hens encounter an antigen, their egg yolks naturally contain large amounts of IgY. A laying hen can

produce over 300 eggs during her lifespan—that is a lot of antibodies! Obtaining antibodies from hen eggs helps scientists practice the 3Rs (Figure 3). First, since large amounts of IgY can be obtained from each egg, eggs can easily be used to *R*eplace the blood of other research animals. Collecting 150 eggs from one hen saves more than 144 mice, so this *R*educes the number of animals used in experiments. Finally, laying eggs is not as painful as having blood drawn, so the antibody-production process has been *R*efined to minimize animal suffering. Thus, the 3Rs are achieved—use of hens improves animal welfare in antibody-production research [4].

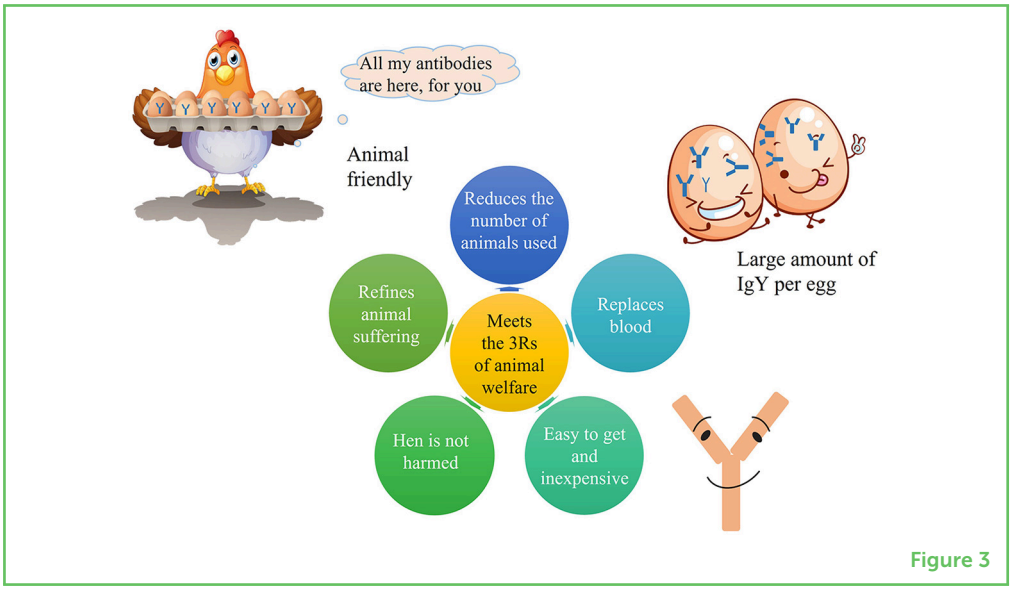

Figure 3

Figure 3

Using hen eggs for antibody production helps scientists to follow the 3Rs to improve animal welfare. A single chicken can produce over 300 eggs over its lifetime and the hen is not harmed by laying eggs. A large amount of IgY is present in each egg and can be easily removed by scientists. Therefore, antibodies from eggs can reduce the number of animals needed for antibody production, replace the need to take blood, and refine the process to decrease animal suffering.

USES OF HEN IgY IN HEALTHCARE

IgY antibodies have many uses in human medicine, for both detection of diseases and disease treatment. In terms of detection, IgY has been used to detect and quantify cancers. Diseases caused by bacteria, such as meningitis or sepsis, can be detected using IgY [5]. IgY can also be used to detect harmful or illegal drugs in human urine. Finally, IgY has also been used to detect the virus that causes severe acute respiratory syndrome, a cousin of COVID-19 [6].

Regarding treatment, IgY has been used in the safe treatment of dental cavities and stomach ulcers [7]. When it comes to treating diseases, IgY has a major advantage over antibodies from mammals, because IgY is not broken down by the body as quickly as mammalian antibodies are. Scientists have also developed clever ways to further protect IgY from the harsh conditions of the gut. So, IgY is a very good drug for treating infections, especially infections of the gut and airways. Who knows—we may soon see a type of IgY that will be useful for treating COVID-19.

SUMMARY

Antibodies are very important molecules, and our bodies produce them to protect us against infections. Antibodies generated in animals such as mice, rabbits, and hens can also be used in healthcare. Hens produce antibodies of a class known as IgY, and these antibodies can be isolated from hen eggs. Hen IgY has advantages over antibodies from other animals and it has been used to safely treat many human and animal diseases. In the future, more diseases will be treated with IgY, further improving human health while also promoting the welfare of laboratory animals.

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ORIGINAL SOURCE ARTICLE

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

ERIN, AGE: 9
Hello, I am a young girl who is interested in Science. When I am with my family, I like to kung-fu my dad, shop with my mom, and watch TV with my younger sister. When I am with my friends, I talk about planning kung-fuing my dad and all. When I am alone, I plan on doing different methods to kung-fu my dad.

HARRISON, AGE: 12
I have a massive enjoyment with sports and outside activities. I love all animals, and when I say all, I mean all. I love playing with my friends online and in person and always play basketball and muck around and do stupid weird things with them. I am a very chatty person, I am always happy and sometimes very crazy. I am passionate with all the sports I play, mainly basketball. I love watching Lebron James and try to learn tricks he does.

JACK, AGE: 16

An avid sport climber and international Taekwondo competitor, I share a passion of advocacy for youth leadership and societal representation in Australia. Even more so, I love being able to constantly learn new things, challenge myself alongside peers, and thrive in STEM environments.

PABLO, AGE: 15

My Name is Pablo, I am half Mexican and half Spanish. I like to read and ask questions to improve my knowledge. I am very fond of science and technology and would like to become an engineer. My hobbies are to play the piano, videogames, football, and padel. I also like animals and cars, especially competition cars. My favorite animal is the eagle, and my favorite car is the Aston Martin Valkyrie. My idols are Adrian Newey and Fernando Alonso.

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