Immunity and Poultry Health (2)

Understanding and Applying Poultry Immunity

"Both the immune system and invading pathogens have the same objective: to survive."

"The best way to view the immune system is to imagine how pathogenic organisms see it. The immune system is their mortal enemy. Their job is to avoid being detected, establish an infection, reproduce, and infect other animals. The immune system's job is to detect the pathogenic 'warriors', remember their faces, and dispatch them before any damage is done."

As we pointed out in Immunity and Poultry Health (1), the scientific field of immunology is changing very rapidly. What we knew yesterday about the immune system might be obsolete tomorrow. To be an immunologist is to be a glutton for punishment, as to 'stay up with the play' means you can never rest; it is a life-long learning curve.

Be that as it may, there are certain key principles of immunology that do not change. In this chapter, we identify the key points of poultry immunology that are most appropriate for developing a working knowledge based on key immunological principles we can easily apply in controlling diseases and using vaccines properly.

Immunologists tend to learn about the immune system the way an auto mechanic rebuilds a car engine, i.e. piece-by-piece from the nuts and bolts until the engine is finished. For those learning about the immune system for the first time, this teaching method is tedious. It is easy to become quickly bogged down in the details of immune responses and miss 'the big picture' of what is important.

In this chapter, we learn first to see 'forest for the trees' of immunity. We don't need to know about all the bits and pieces; but following the illustration with the auto mechanic, if we want to drive a car then we do need to know how to drive it safely and learn to maintain it in good condition so it is always reliable. If all we do is learn to fill the car up with petrol and drive away ignoring care and maintenance, eventually the engine packs up and the wheels fall off!

It's the same with poultry vaccination. If we neglect to understand how immunity and vaccination work, we are going to be tempted to take short cuts and dismiss the crucial details. The result is poor immunity and degraded animal welfare. The wheels simply fall off our poultry operation.

When the wheels fall off, the most used excuse is 'the vaccine is no good'. Unfortunately, the greatest cause of 'vaccination failure' is the inattention to detail and mistakes made by the person responsible for carrying out the vaccination.

The Elegant Design of the Immune System

We start by looking at the overall design of the immune system and then look at how it detects and processes invading organisms (that can infect the chicken and cause a disease which we call 'pathogens' or 'pathogenic organisms').

The immune system is one of the most elegant and practical designs there is. It is self-contained. It is self-renewing. It detects. It transports. It communicates. It memorises. It turns on. It turns off. It processes. It cleans. It protects.

From the moment a chicken is hatched, the immune system provides the necessary means for the chicken to protect itself and its young from potential exposure to diseases.

Let's start by seeing the immune system through the view of an invading pathogenic organism:

A pathogenic organism is a virus, bacteria or parasite that infects an animal. Each pathogen's main purpose in life is to infect, reproduce, and re-infect in order to maintain the survival of its species. To fulfil its survival instincts, pathogens have to be able to evade the immune system in some manner.

To evade detection and defeat the immune system, pathogens use a range of 'virulence factors.' These virulence factors are basically a 'bag of tricks' that the pathogen has to sneak through all the barriers and detection devices the immune system uses to block and eliminate infectious agents.

Virulence factors allow pathogens to 'fly under the radar' and beat immune defences. They can hide in cells or literally 'hijack' cells so they can hitchhike their way to other parts of the body where they finally reproduce themselves, kill the cell, and release new organisms that can re-infect other cells.

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"Thank goodness... it's the battery hen".

Some pathogens deliberately infect and use cells to replicate themselves; then they kill the cell and release more organisms to infect more cells of the animal. Pathogens that infect cells and reproduce inside them are called 'intracellular' organisms. 'Extracellular' organisms are those that infect animals but generally live and reproduce outside "Thank goodness... it's the battery hen". of the cells.

Whether a pathogen is intracellular or extracellular is relevant for us in understanding and applying immunity. We will discuss how this decides what kind of immune response is generated later in this chapter.

To meet the various infection strategies of pathogens, the immune system also keeps many tricks up its own sleeve to counter the invaders. An invading pathogen has to confront an immune system that is highly organised to detect and eliminate foreign agents.

The immune system is organised like an army of millions of soldiers grouped into combat branches, intelligence operations and a signal corps that work together to defeat an enemy invasion. The role of these branches is to respond to an invading pathogen with a series of protective defence barriers designed to first block the invader out. If the invader persists, the immune system signals for the infantry to come and take out the pathogen and eliminate it from the animal's body.

There are two branches of the immune system: innate and adaptive immunity. A pathogen intent on infecting a chicken has to find a way to penetrate both innate and adaptive immunity to set up the infection.

Innate Immunity

The first branch, innate immunity, is the first barrier pathogens 'see' in the immune system. Innate immunity is the equivalent of the fortifications surrounding a castle with a series of moats, barriers, and soldiers fighting from the ramparts. Innate immunity does not recognise specific pathogens, i.e. it does not discriminate. It is a general series of defensive mechanisms designed to block, disable and eliminate any invaders from entering the chicken's tissue and setting up an infection and creating disease.

We picture innate immunity as having four different kinds of barriers to stop pathogens:

- **Anatomic barriers:** Skin, feathers, and mucosal membranes.
- **Physiologic barriers:** Body temperature, acidic environment of stomach, chemical mediators.
- **Phagocytic barriers:** Different types of phagocytic cells that we often call 'white blood cells' that are able to ingest and digest entire pathogens and foreign substances.
- **Inflammatory barriers:** Blood serum that carries anti-bacterial substances and white blood cells to sites of tissue damage and to where infection has occurred.

"Don't tell me... wev'e run out of boiling oil again"!

As with the invasion of a castle, pathogens have to find a way to get themselves across these innate barriers. It is not unlike an invasion of a castle, with marauding invaders trying to cross the moat, break down the castle door, climb over the castle walls and overwhelm the archers and swordsmen on the ramparts.

To break through these barriers, pathogens invade like a large horde using their numbers to overwhelm the defences and use different tactics to break through immune defences.

As with humans, the easiest and most popular route of infection is through the nose and mouth where access is the most direct to find cells to infect in the respiratory or intestinal tracts. Anatomic barriers act as the castle walls as a physical obstacle to be penetrated.

Physiological barriers are chemical reactions that act like hot oil being poured over the castle ramparts on top of the invaders. Phagocytic barriers are the soldiers on the ramparts that can directly kill the invading pathogen. The inflammatory barriers are the reinforcements that are called up from the castle to support the ramparts.

Pathogens reach into their bag of tricks (virulence factors) and just like using catapults, ladders, armour, and rams to invade a castle, they will attach themselves to tissue, hide and reproduce in cells, and even hijack cells to be transported around the body. In the most hideous tactics, pathogens such as Infectious Bursal Disease Virus (IBDV) attack the foundation cells of the immune system first and disable it before any immunity can be mustered.

Adaptive (or Specific) Immunity

If the invading pathogen is successful to get over or through the castle walls of the innate immune defences, adaptive immunity is waiting to swarm the hordes as they come over the wall, with an armoury of antibodies and mechanisms to kill infected cells and stop the infection from spreading.

Adaptive immunity is pathogen specific and is often referred to as specific immunity. It recognises and remembers specific viruses, bacteria, or parasitic organisms and is able to generate immune responses that are specific to eliminating that particular organism.

The chicken's adaptive immune system is based on the cells of two important organs: the thymus and the Bursa of Fabricius. The immune cells developed in the thymus are called T lymphocytes (or 'T cells'). Those that develop in the bursa are known as B lymphocytes (or 'B' cells). These two types of cells and their subsets make up the ranks of millions of the soldiers that learn to specifically recognise, memorise and destroy pathogens. Most importantly, T cells and B cells generate different types of immunity, as we will see.

As we mentioned above, whether a pathogen is an intracellular or extracellular organism, how they infect an animal's tissue cells decides which way the immune system will attempt to check the infection and eliminate the pathogen. This is one of the most important principles of immunology to remember.

Cell-Mediated Immunity

Intracellular pathogens generate what is known as cell-mediated immunity (CMI for short). Intracellular pathogens can infect any cell with a nucleus. A nucleated cell is able to attack and process the foreign invader into small protein packages called 'peptides'. These peptides are then attached to another protein molecule and carried to the cell surface where they act as 'signals' to flag down the immune system's T cells. A T cell then recognises the specific peptide, attaches itself to the infected cell and finally kills the cell and its 'resident' pathogen. These T cells are known as cytotoxic T lymphocytes (CTL) and are the primary 'soldiers' or 'effector' cells of the cell-mediated response.

The effector CTL soldiers are complemented by another subset of T cells known as memory T cells that have the primary function of retaining the memory to recognise a specific pathogen and generate new CTL if the pathogen invades again. Therefore, memory T cells are critical for the chicken to be able to respond to a future infection.

When we vaccinate, our objective is to build up the level of memory cells so there will be ample cells to respond to an infection. When we give 'booster shots' with a live vaccine, what we are really doing is 'boosting' the number of available memory T cells.

CMI is a very powerful response and particularly useful at the most common portals of infection in the respiratory and intestinal tissues. Live vaccines are used to prime the T cells residing in the tissue at these infection portals. The immune response created is robust and able to quickly stop a pathogen before it can infect the chicken any further and cause disease.

Antibody-Mediated Immunity

While intracellular organisms generate cell-mediated immunity, extracellular organisms are processed by specialised immune system cells to create antibody-mediated immunity. This is also known as 'humoral' immunity and is found in the primary secretions and body fluids from tears, nasal secretions, saliva, and the serum component of blood.

The immune system relies on a set of cells called antigen-presenting cells (APCs) that ingest and process extracellular pathogens. Similar to the cell-mediated processing of pathogens above, these extracellular pathogens are digested and their peptide components are mounted on another molecule and placed on the cell's surface where it signals the immune system. In this case, however, another type of T cell known as helper T cells attach themselves to the antigen-presenting cell and generate a signal to B cells to multiply and differentiate into antibody producing plasma cells and memory B cells.

We have all heard of antibodies but probably know very little about them.

Antibodies are proteins that recognise a specific pathogen, bind to the pathogen, and eliminate it from the chicken before it can cause further infection. Each plasma cell will only produce one kind of antibody, against one specific pathogen.

In the chicken, there are three kinds of antibodies (also known as immunoglobins) which are called IgM, IgG, and IgA. It is very helpful to understand where each antibody is generally found and what it does:

IgM: This is the first antibody created in a primary immune response against an invading pathogen. It is generally found circulating in the bloodstream and associated primarily with blood-borne infections. While not available in large volumes, it is the largest-sized antibody and capable of strong interaction with other immune system components to neutralise and eliminate large numbers of organisms rapidly.

IgG *(also known as IgY in chickens)*:
This is the real 'workhorse' antibody of humoral immunity and the most important antibody in secondary immune responses as seen after 'booster' vaccinations. IgG is generally confined to the bloodstream but is available in very large volumes to eliminate foreign organisms. IgG is the antibody found in yolks that enables passive immunisation of chicks.

IgA: This is an important antibody because of its ability to be secreted through the mucosal membrane tissues and attach to incoming pathogens in the respiratory and intestinal systems.

The poultry industry often takes blood serum from vaccinated chickens. This is to measure the level of antibodies as a measure of the immune response to the vaccine and an indication of the amount of protection against the specific disease.

Active and Passive Immunity

The elegance of the immune system is seen in its ability to provide immune protection for both the hen and its chick.

As newborn chicks do not have a mature immune system, the hen secretes large quantities of IgG into the egg yolk that can be absorbed into the bloodstream of the baby chick. This is known as passive immunity. It is an important facet of poultry vaccination as we exploit the hen's immune system by incorporating vaccines that hyper immunise the breeding hen to enable consistently high levels of protective antibodies are in the yolk for the chick.

Active immunity is the term we use to describe the chicken's own immune protection. This is of course the basis of most other vaccinations for poultry as our intention is to provide high levels of active protection in the chicken to ward off invading disease pathogens.

Final Point

Understanding the basic concept of immunity is important when we use vaccines. By knowing how vaccines work and elicit an immune response, we become more aware of the need to be meticulous in the application of vaccines and the husbandry of poultry to keep them free of disease. The goal is to eliminate as many potential pathogenic invaders as we can through good biosecurity and farm management. Vaccines are never a substitute for skilled husbandry but are insurance against disease when things break down or when pathogens such as Marek's Disease virus or Coccidiosis are present.