

How Breast Milk Protects Newborns

Some of the molecules and cells in human milk actively help infants stave off infection

by Jack Newman

Doctors have long known that infants who are breast-fed contract fewer infections than do those who are given formula. Until fairly recently, most physicians presumed that breast-fed children fared better simply because milk supplied directly from the breast is free of bacteria. Formula, which must often be mixed with water and placed in bottles, can become contaminated easily. Yet even infants who receive sterilized formula suffer from more meningitis and infection of the gut, ear, respiratory tract and urinary tract than do breast-fed youngsters.

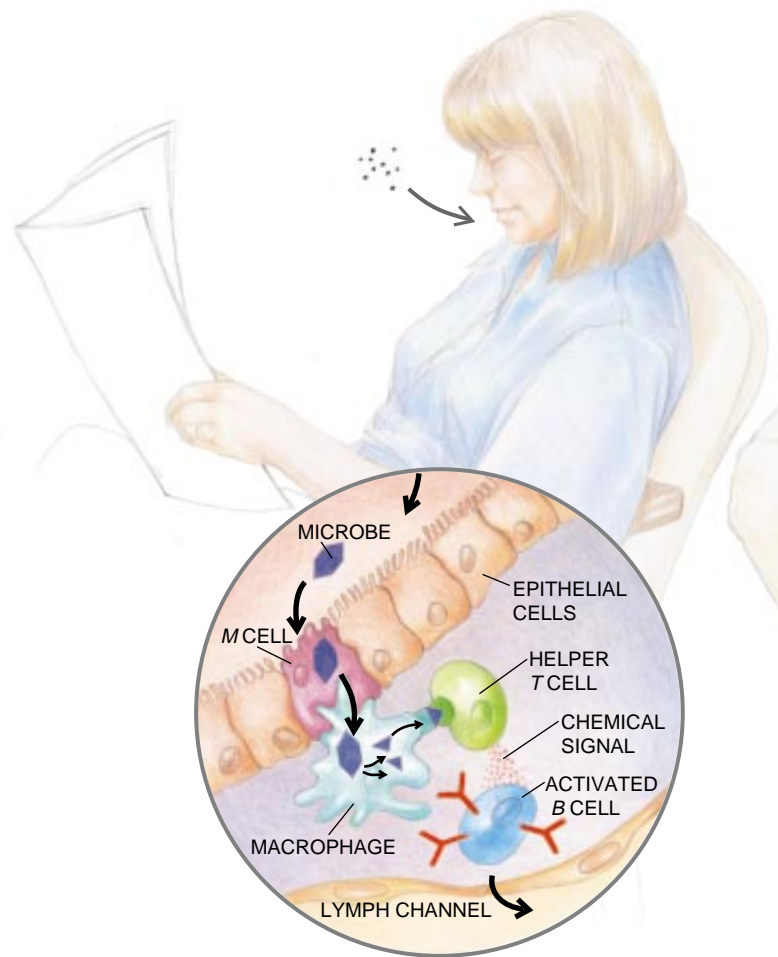
The reason, it turns out, is that mother's milk actively helps newborns avoid disease in a variety of ways. Such assistance is particularly beneficial during the first few months of life, when an infant often cannot mount an effective immune response against foreign organisms. And although it is not the norm in most industrial cultures, UNICEF and the World Health Organization both advise breast-feeding to "two years and beyond." Indeed, a child's immune response does not reach its full strength until age five or so.

All human babies receive some coverage in advance of birth. During pregnancy, the mother passes antibodies to her fetus through the placenta. These proteins circulate in the infant's blood for weeks to months after birth, neutralizing microbes or marking them for destruction by phagocytes—immune cells that consume and break down bacteria, viruses and cellular debris. But breast-fed infants gain extra protection from antibodies, other proteins and immune cells in human milk.

Once ingested, these molecules and cells help to prevent microorganisms from penetrating the body's tissues. Some of the molecules bind to microbes in the hollow space (lumen) of the gastrointestinal tract. In this way, they block microbes from attaching to and crossing through the mucosa—the layer of cells, also known as the epithelium, that lines the digestive tract and other body cavities. Other molecules lessen the supply of particular minerals and vitamins that harmful bacteria need to survive in the digestive tract. Certain immune cells in human milk are phagocytes that attack microbes directly. Another set produces chemicals that invigorate the infant's own immune response.

Breast Milk Antibodies

Antibodies, which are also called immunoglobulins, take five basic forms, denoted as IgG, IgA, IgM, IgD and IgE. All have been found in human milk, but by far the most abundant type is IgA, specifically the form known as secretory IgA, which is found in great amounts throughout the



AFTER INGESTING A MICROBE (left), a new mother manufactures antibody molecules termed secretory IgA that enter breast milk (center) and help to protect the breast-fed baby from pathogens in its environment (right). More specifically, a microbe is taken up by the mother's M cells (inset at left)—specialized cells in the epithelial lining of the digestive tract—

gut and respiratory system of adults. These antibodies consist of two joined IgA molecules and a so-called secretory component that seems to shield the antibody molecules from being degraded by the gastric acid and digestive enzymes in the stomach and intestines. Infants who are bottle-fed have few means for battling ingested pathogens until they begin making secretory IgA on their own, often several weeks or even months after birth.

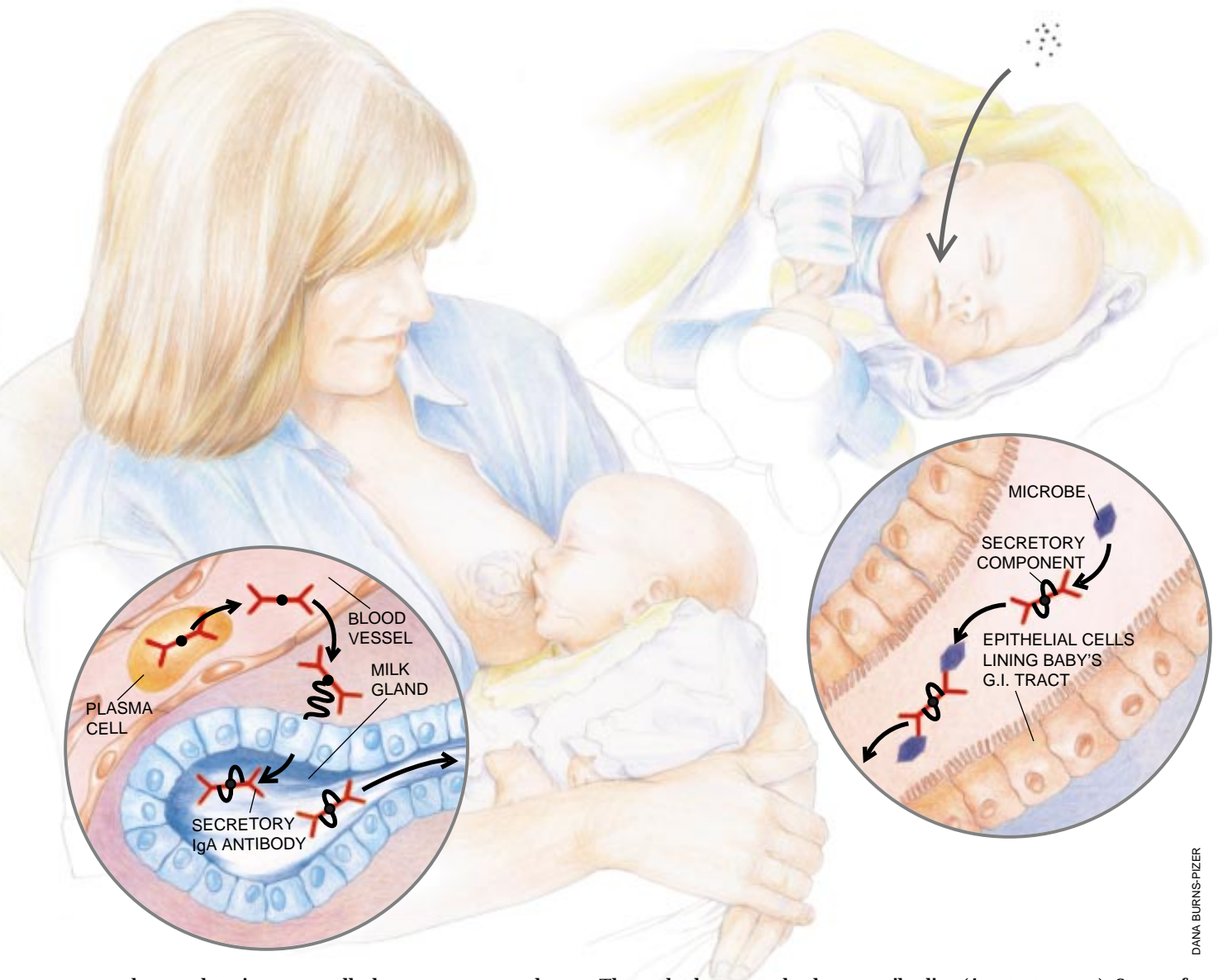
The secretory IgA molecules passed to the suckling child are helpful in ways that go beyond their ability to bind to microorganisms and keep them away from the body's tissues. First, the collection of antibodies transmitted to an

infant is highly targeted against pathogens in that child's immediate surroundings. The mother synthesizes antibodies when she ingests, inhales or otherwise comes in contact with a disease-causing agent. Each antibody she makes is specific to that agent; that is, it binds to a single protein, or antigen, on the agent and will not waste time attacking irrelevant substances. Because the mother makes antibodies only to pathogens in her environment, the baby receives the protection it most needs—against the infectious agents it is most likely to encounter in the first weeks of life.

Second, the antibodies delivered to the infant ignore useful bacteria normally found in the gut. This flora serves to

crowd out the growth of harmful organisms, thus providing another measure of resistance. Researchers do not yet know how the mother's immune system knows to make antibodies against only pathogenic and not normal bacteria, but whatever the process may be, it favors the establishment of "good bacteria" in a baby's gut.

Secretory IgA molecules further keep an infant from harm in that, unlike most other antibodies, they ward off disease without causing inflammation—a process in which various chemicals destroy microbes but potentially hurt healthy tissue. In an infant's developing gut, the mucosal membrane is extremely delicate, and an excess of these



and passed to immune cells known as macrophages. The macrophages break down the pathogen and display fragments of it (antigens) to other immune cells called helper *T* lymphocytes, which secrete chemicals that activate still other immune cells, *B* lymphocytes. The *B* cells, in turn, mature into so-called plasma cells that travel to epithelial tissues in

the breast and release antibodies (*inset at center*). Some of these molecules enter the milk and are swallowed by the baby. In the infant's digestive tract (*inset at right*), the antibodies, which are protected from breakdown by a so-called secretory component, prevent microorganisms from penetrating the baby's gut.

DANA BURNS-PZER

Immune Benefits of Breast Milk at a Glance

Component	Action
White Blood Cells	
B lymphocytes	Give rise to antibodies targeted against specific microbes.
Macrophages	Kill microbes outright in the baby's gut, produce lysozyme and activate other components of the immune system.
Neutrophils	May act as phagocytes, ingesting bacteria in baby's digestive system.
T lymphocytes	Kill infected cells directly or send out chemical messages to mobilize other defenses. They proliferate in the presence of organisms that cause serious illness in infants. They also manufacture compounds that can strengthen a child's own immune response.
Molecules	
Antibodies of secretory IgA class	Bind to microbes in baby's digestive tract and thereby prevent them from passing through walls of the gut into body's tissues.
B ₁₂ binding protein	Reduces amount of vitamin B ₁₂ , which bacteria need in order to grow.
Bifidus factor	Promotes growth of <i>Lactobacillus bifidus</i> , a harmless bacterium, in baby's gut. Growth of such nonpathogenic bacteria helps to crowd out dangerous varieties.
Fatty acids	Disrupt membranes surrounding certain viruses and destroy them.
Fibronectin	Increases antimicrobial activity of macrophages; helps to repair tissues that have been damaged by immune reactions in baby's gut.
Gamma-interferon	Enhances antimicrobial activity of immune cells.
Hormones and growth factors	Stimulate baby's digestive tract to mature more quickly. Once the initially "leaky" membranes lining the gut mature, infants become less vulnerable to microorganisms.
Lactoferrin	Binds to iron, a mineral many bacteria need to survive. By reducing the available amount of iron, lactoferrin thwarts growth of pathogenic bacteria.
Lysozyme	Kills bacteria by disrupting their cell walls.
Mucins	Adhere to bacteria and viruses, thus keeping such microorganisms from attaching to mucosal surfaces.
Oligosaccharides	Bind to microorganisms and bar them from attaching to mucosal surfaces.

chemicals can do considerable damage.

Interestingly, secretory IgA can probably protect mucosal surfaces other than those in the gut. In many countries, particularly in the Middle East, western South America and northern Africa, women put milk in their infants' eyes to treat infections there. I do not know if this remedy has ever been tested scientifically, but there are theoretical reasons to believe it would work. It probably does work at least some of the time, or the practice would have died out.

An Abundance of Helpful Molecules

Several molecules in human milk besides secretory IgA prevent microbes from attaching to mucosal surfaces. Oligosaccharides, which are simple chains of sugars, often contain domains that resemble the binding sites through which bacteria gain entry into the cells lining the intestinal tract. Thus, these sugars can intercept bacteria, forming harmless complexes that the baby excretes. In addition, human milk contains large molecules called mucins that include a great deal of protein and carbohydrate. They, too, are capable of adhering to bacteria and viruses and eliminating them from the body.

The molecules in milk have other valuable functions as well. Each molecule of a protein called lactoferrin, for example, can bind to two atoms of iron. Because many pathogenic bacteria thrive on iron, lactoferrin halts their spread by making iron unavailable. It is especially effective at stalling the proliferation of organisms that often cause serious illness in infants, including *Staphylococcus aureus*. Lactoferrin also disrupts the process by which bacteria digest carbohydrates, further limiting their growth. Similarly, B₁₂ binding protein, as its name suggests, deprives microorganisms of vitamin B₁₂.

Bifidus factor, one of the oldest known disease-resistance factors in human milk, promotes the growth of a beneficial organism named *Lactobacillus bifidus*. Free fatty acids present in milk can damage the membranes of enveloped viruses, such as the chicken pox virus, which are packets of genetic material encased in protein shells. Interferon, found particularly in colostrum—the scant, sometimes yellowish milk a mother produces during the first few days after birth—also has strong antiviral activity. And fibronectin, present in large quantities in colostrum, can make certain phagocytes more aggressive so that they will ingest microbes even when the microbes have not been tagged by an antibody. Like secretory IgA, fibronectin minimizes inflamma-

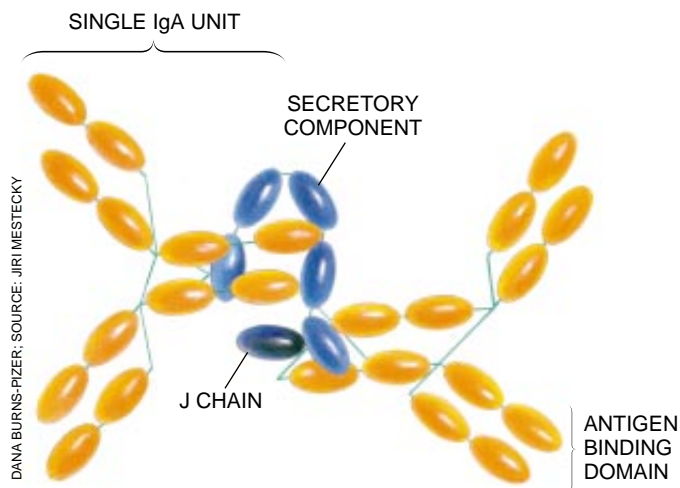
tion; it also seems to aid in repairing tissue damaged by inflammation.

Cellular Defenses

As is true of defensive molecules, immune cells are abundant in human milk. They consist of white blood cells, or leukocytes, that fight infection themselves and activate other defense mechanisms. The most impressive amount is found in colostrum. Most of the cells are neutrophils, a type of phagocyte that normally circulates in the bloodstream. Some evidence suggests that neutrophils continue to act as phagocytes in the infant's gut. Yet they are less aggressive than blood neutrophils and virtually disappear from breast milk six weeks after birth. So perhaps they serve some other function, such as protecting the breast from infection.

The next most common milk leukocyte is the macrophage, which is phagocytic like neutrophils and performs a number of other protective functions. Macrophages make up some 40 percent of all the leukocytes in colostrum. They are far more active than milk neutrophils, and recent experiments suggest that they are more motile than are their counterparts in blood. Aside from being phagocytic, the macrophages in breast milk manufacture lysozyme, increasing its amount in the infant's gastrointestinal tract. Lysozyme is an enzyme that destroys bacteria by disrupting their cell walls.

In addition, macrophages in the digestive tract can rally lymphocytes into action against invaders. Lymphocytes constitute the remaining 10 percent of white cells in the milk. About 20 percent of these cells are *B* lymphocytes, which give rise to antibodies; the rest



SECRETORY IgA ANTIBODY, depicted schematically, consists of two IgA molecules “glued” together by a protein fragment known as the J chain. The secretory element (blue) wraps around the joined molecules. The ellipses represent functional domains. Each of the four arms in such antibodies contains an antigen binding domain.

are *T* lymphocytes, which kill infected cells directly or send out chemical messages that mobilize still other components of the immune system. Milk lymphocytes seem to behave differently from blood lymphocytes. Those in milk, for example, proliferate in the presence of *Escherichia coli*, a bacterium that can cause life-threatening illness in babies, but they are far less responsive than blood lymphocytes to agents posing less threat to infants. Milk lymphocytes also manufacture several chemicals—including gamma-interferon, migration inhibition factor and monocyte chemoattractant factor—that can strengthen an infant's own immune response.

Added Benefits

Several studies indicate that some factors in human milk may induce an infant's immune system to mature more quickly than it would were the child fed artificially. For example, breast-fed babies produce higher levels of antibodies in response to immunizations.

Also, certain hormones in milk (such as cortisol) and smaller proteins (including epidermal growth factor, nerve growth factor, insulin-like growth factor and somatomedin C) act to close up the leaky mucosal lining of the newborn, making it relatively impermeable to unwanted pathogens and other potentially harmful agents. Indeed, animal studies have demonstrated that postnatal development of the intestine occurs faster in animals fed their mother's milk. And animals that also receive colostrum, containing the highest concentrations of epidermal growth factor, mature even more rapidly.

Other unknown compounds in human milk must stimulate a baby's own production of secretory IgA, lactoferrin and lysozyme. All three molecules are found in larger amounts in the urine of breast-fed babies than in that of bottle-fed babies. Yet breast-fed babies cannot absorb these molecules from human milk into their gut. It would appear that the molecules must be produced in the mucosa of the youngsters' urinary tract. In other words, it seems that breast-feeding induces local immunity in the urinary tract.

In support of this notion, recent clinical studies have demonstrated that the breast-fed infant has a lower risk of acquiring urinary tract infections. Finally, some evidence also suggests that an unknown factor in human milk may cause breast-fed infants to produce more fibronectin on their own than do bottle-fed babies.

All things considered, breast milk is truly a fascinating fluid that supplies infants with far more than nutrition. It protects them against infection until they can protect themselves.

The Author

JACK NEWMAN founded the breast-feeding clinic at the Hospital for Sick Children in Toronto in 1984 and serves as its director. He has more recently established similar clinics at Doctors Hospital and St. Michael's Hospital, both in Toronto. Newman received his medical degree in 1970 from the University of Toronto, where he is now an assistant professor. He completed his postgraduate training in New Zealand and Canada. As a consultant for UNICEF, he has worked with pediatricians in Africa. He has also practiced in New Zealand and in Central and South America.

Further Reading

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