

## Breastfeeding

*Nurse: why is breast milk best for my baby?*



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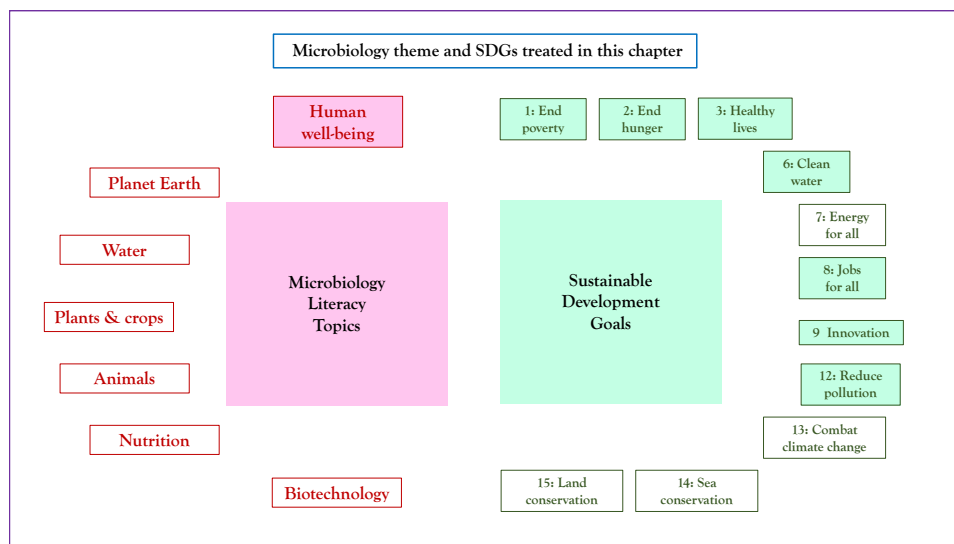
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### Storyline

A baby has complex nutritional needs to support brain development, physical growth, and immune maturation. Amazingly, mothers produce a tailored fluid designed especially for their offspring that contains nutrients, immune factors, prebiotics that promote the growth of beneficial bacteria in the infant gut, and also live microbes. This special fluid is milk and is a feature of all mammals (from the word ‘mammary’ gland). The first milk produced by the breast is called colostrum, which is produced in small volumes but contains high levels of antibodies and other components to nourish and protect the newborn baby. In the days following birth, milk composition slowly changes to reflect the changing growth demands of the baby. Over the course of lactation (which may last for years), the bacteria that are transferred from mother-to-infant, and also from infant-to-mother will also change, as will the prebiotic composition in the milk. Prebiotics refer to various components that promote the growth of healthy bacteria. While breast milk substitutes such as bovine-derived formula milk are available, these are sterile and do not contain the hundreds of unique human components (such as certain prebiotics) that are essential to supporting the growth of beneficial bacteria. Put simply, no alternatives or substitutes come close to supporting the short- and long-term health needs of newborn babies than the complex and tailored milk produced by an infant’s own mother. For this reason, the World Health Organisation (WHO) recommends exclusive breastfeeding for at least the first 6 months of life, after which complementary foods can be introduced while continuing to breastfeed for up to 2 years and beyond. Large epidemiological studies have highlighted that infants receiving breast milk in the first 12 months have a lower chance of developing allergies, asthma, and obesity, and they have better cognition later in life. There are also health benefits to the mother, with evidence that breastfeeding can reduce the risk of breast and ovarian cancer, cardiovascular disease, strokes, and depression.

### The Microbiology and Societal Context



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*The microbiology:* microbiome and microbiota transfer; human milk oligosaccharide prebiotics; beneficial microbes; microbial colonisation of the infant gut; pathogens; colostrum and sIgA; immune training; *Sustainability issues:* environmental footprint of cows' milk; poverty, hunger; health; clean water; employment; pollution.

### Breastfeeding: the Microbiology

**1. Breastfeeding provides microbes that colonise the infant gut.** Multiple studies using different methodologies have shown that breast milk contains living bacteria. As such, this represents one way that a mother directly passes microbes to her baby. How bacteria enter the breast milk is still an area of active investigation, with some evidence they may migrate from the gut. There is also strong evidence that bacteria in the baby's mouth can pass into the breast milk during feeding at the breast ('backwash'). This 2-way transfer of microbes might have important consequences as 'feedback' from the baby may enable a mother to tailor the breast milk for her infant, for example make antibodies against potentially harmful bacteria.

While the microbes passed from mother to infant are usually commensal or beneficial (i.e., generally good for humans), in some instances they can be pathogenic (i.e., generally bad for humans). For instance, breast milk can contain human immunodeficiency virus (HIV) which can be transmitted to the baby during feeding. Without intervention strategies, an estimated 11–42% of infants of mothers who are positive for the virus can become infected with HIV.

**2. Breast milk contains nutrients that feed the microbes in the infant gut.** Breast milk has numerous roles of which the most important are to provide the infant with nutrients that are essential for brain development and physical growth. These nutrients include the main macronutrients (e.g., fats, carbohydrates and protein), minerals (e.g., calcium, phosphorus, magnesium) trace elements (e.g., iron and zinc) and vitamins (e.g., thiamine, riboflavin, vitamin B6, vitamin C). While these nutrients are used by the infant, they can also be used by the bacteria that live in the intestine. These bacteria are collectively referred to as the gut microbiome.

**3. Breast milk contains prebiotics that specifically support the growth of beneficial bacteria.** Although we discussed in point 1 that breast milk can provide bacteria directly to the infant, only some of the bacteria in breast milk are considered colonisers of the early infant gut microbiome. Most of the dominant bacteria in breast milk are found on the skin and in the oral community, for example *Staphylococcus* and *Streptococcus*.

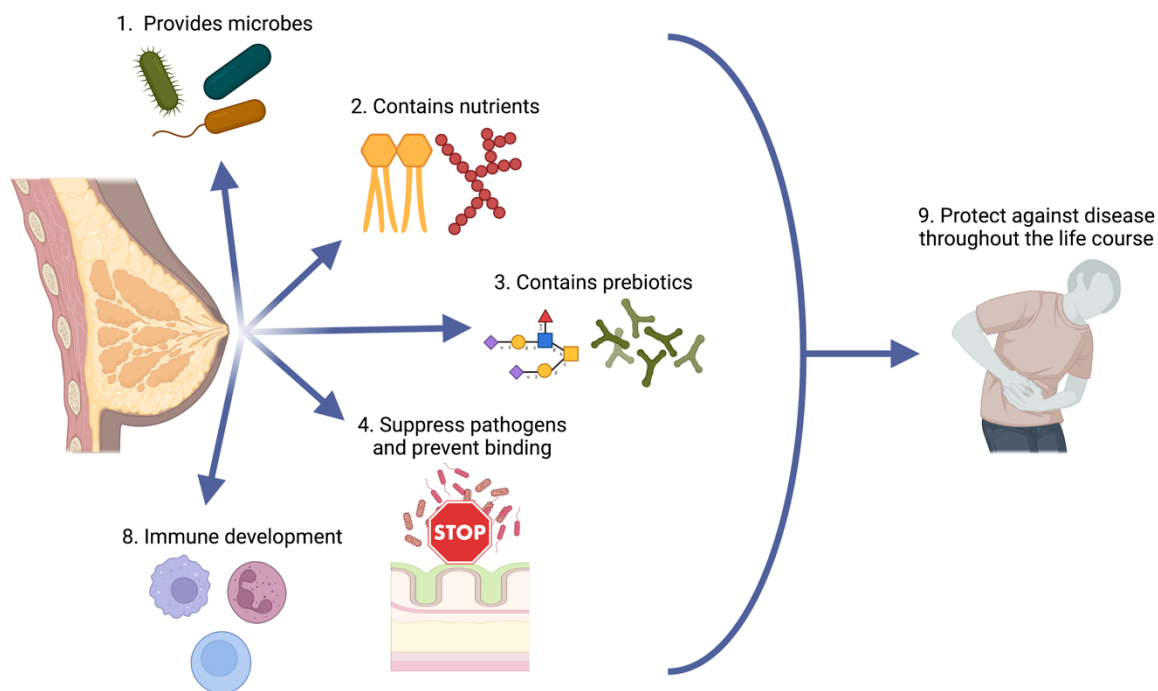
Scientists have recently begun to explore what specific components of breast milk shape the infant gut and promote the growth of beneficial gut bacteria. These components would be considered 'prebiotics'. Of these, the most abundant group of prebiotics in human milk are human milk oligosaccharides (HMOs). HMOs are the 3rd most abundant solid component of breast milk but humans lack the enzymes to digest them and they therefore have no nutritional value to the infant. This means they reach the lower intestine intact, where they can be broken down by beneficial bacteria, especially *Bifidobacterium*. When an infant stops receiving breast milk, *Bifidobacterium* levels decline rapidly and they are replaced by bacteria more often seen in adults, reflecting a more adult-like diet.

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Lastly, although HMOs are generally considered prebiotics, they may also directly impact the immune system and have been linked to health status. An example of this is preterm infants who are at risk of a deadly intestinal disease called necrotising enterocolitis, where lack of a single HMO disialyllacto-N-tetraose in breast milk can increase the risk of developing the disease.

**4. Breast milk contains components that can suppress pathogen growth and prevent pathogen binding to the host.** Although the gut microbiome is important for health overall, it must be kept in check. Breast milk contains many factors to both prevent and promote bacterial colonisation and provide control of the microbiome. One such component is secretory immunoglobulin A (sIgA), which serves as the first line of defense in protecting the intestinal epithelium from pathogenic bacteria. sIgA is abundant in colostrum and early breast milk, because the infant is unable to produce its own IgA until around 1 month of life. Therefore, if an infant does not receive breast milk over the first month of life they lack sIgA in the gut. This can allow potentially pathogenic bacteria to overgrow, which will alter immune development, and may increase the risk of disease for the infant.

In addition, HMOs, while primarily prebiotics, have also been shown to bind to pathogenic bacteria and prevent them binding to the host epithelium. Here, the HMOs can act as a 'decoy receptor' and prevent disease, but the precise mechanisms remain unclear.



**5. Expressing breast milk impacts on the pattern of microbes.** When an infant feeds directly at the breast, they receive bacteria from the breast milk and mothers surrounding skin. However, it is not always possible for a baby to feed directly from the breast, for instance if a baby is sick and premature, or when a mother returns to work. In this case, breast milk can be expressed and stored in bottles and given to the infant at a later time. Recent work has shown that the bacteria in expressed breast milk has higher levels of potential pathogens and a depletion of the

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beneficial bacteria *Bifidobacterium*. Nonetheless, the benefits of using expressed breast milk when direct feeding is not possible will still outweigh the alternative option of using formula milk that does not contain sIgA, HMOs, and other important components.

**6. *Pasteurisation of donor milk kills the microbes.*** So far, we have considered mothers' own breast milk or bovine milk-derived formula. Another option is to use donated human breast milk, which is breast milk from another mother that has been donated and pasteurised. This milk will not be tailored for the infant and will lack bacteria due to pasteurisation, but will still contain many other important components (e.g., sIgA and HMOs) that are generally lacking in infant formula.

Using another woman's milk is not a new concept. Before the availability of formula milk in the 20th century, 'wet nurses' were regularly used to provide life-saving nutrition, a practice that dates back thousands of years. Pasteurisation is used routinely to ensure the safety of donor milk (e.g., ensure no transmission of pathogens such as HIV). Recent studies have explored whether reintroducing healthy microbes back into the milk, by adding small amounts of mothers' own milk to donor milk is helpful.

**7. *Formula milk lacks microbes and has a greater adverse environmental impact.*** Breast milk is the most natural 'food product' on the planet and provides the optimal nutrition for an infant with a low 'carbon footprint'. Notwithstanding, some mothers may be unable to provide any milk or sufficient milk to feed their infant, or may choose not to breastfeed for other reasons. Commercial formula milk is far safer than unmodified animal milks, has unquestionably saved lives, and provides an essential product in certain situations.

That said, the farming and manufacturing process of bovine milk has significant environmental impacts. Dairy cows and their manure produce greenhouse gas emissions, especially methane, which contribute to climate change. Poor farming practices can also lead to pollution of water and damage to wildlife. Most recent estimates suggest cows' milk has a water footprint of up to 4,700 litres per kilogram of powder. Producing powdered formula, typically stored in plastic containers, and transporting the product globally has further adverse impacts on energy use and climate change.

**8. *Breast milk contributes directly and indirectly to infant immune system development.*** Immune factors in human milk can impact the immune system directly (e.g., cytokines, growth factors, lactoferrin) and indirectly (e.g., microbes). Cytokines are signaling molecules that help the body's immune and inflammation responses. Cytokines from breast milk can cross the infant's intestinal barrier and mediate immune activity. Lactoferrin is enriched in human milk compared to bovine milk and can bind to free iron in the intestine and reduce the availability of this substrate needed by potentially pathogenic bacteria such as *E coli*. Moreover, lactoferrin also modulates immunity by blocking inflammatory signaling cytokines. Lastly, microbes from breast milk have direct and specific impacts on the education of the infant's immune system.

**9. *Breastfeeding protects against disease throughout the life course.*** Large epidemiological studies have highlighted that receiving breast milk in the first 12 months can reduce the risk of developing allergies, asthma, obesity, and improve brain outcome in later life. For an infant born

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prematurely, receiving mother's own breast milk is the most protective factor in reducing the risk of a deadly disease called necrotising enterocolitis.

There are also health benefits to the mother, with evidence that breastfeeding can reduce the risk of breast and ovarian cancer, cardiovascular disease, strokes, and depression. It is well reported that genetics, lifestyle, diet, and age can impact the breast milk microbiome and bioactive components, although more work is needed to understand this and make personalised dietary recommendations for mothers. Considering this, differences in the composition of breast milk might explain why some breastfed infants still develop disease.

### Relevance for Sustainable Development Goals and Grand Challenges

- **Goal 1. End poverty.** Poverty threatens breastfeeding, both directly and indirectly. Babies born to mothers living in poverty are less likely to be breastfed in high-income 'westernized' countries, although the reverse may occur in low-income settings. In certain resource-poor settings, women may return to work soon after childbirth for financial reasons. Furthermore, many women in resource-poor settings may be undernourished, which can impact the amount and composition of breast milk they can produce.
- **Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture** (*end hunger and malnutrition, increase agricultural productivity*). If mothers are unable to sufficiently nourish themselves this will have negative consequences for the nourishment of their infant. Once an infant is old enough to be weaned onto solid foods, it is also important they have access to sufficient and nourishing food.
- **Goal 3. Ensure healthy lives and promote well-being for all at all ages** (*improve health, reduce preventable disease and premature deaths*). Healthy mothers who breastfeed promote short- and long-term health in their infant and this must be encouraged and supported. Conversely, extensive and potentially misleading advertising of infant formula can lead to confusion and reduce breastfeeding rates.
- **Goal 6. Ensure availability and sustainable management of water and sanitation for all** (*assure safe drinking water, improve water quality, reduce pollution, protect water related ecosystems, improve water and sanitation management*). Access to clean water and hygiene is essential for infant formulas to prevent contamination that can cause illness or death. Like all milks, breast milk is composed of large amounts of water and therefore provides clean water for infants.
- **Goal 8: Promote sustained, inclusive, and sustainable economic growth, full and productive employment and decent work for all** (*promote economic growth, productivity and innovation, enterprise and employment creation*). Many marginalised populations have less access to fair working conditions, employer support for maternity leave, and social support for the most disadvantaged, all of which can impact breastfeeding rates and mother and infant health. Further economic growth can improve poverty, clinical care and lactation support, public health measures, and general hygiene, leading to improved capacity to safely breastfeed and/or supplement infants.
- **Goal 9: Industry, Innovation, Infrastructure** (*development of biotechnology and medical equipment*). Technical innovations are essential to continuously improve expression of

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breast milk and improve infant formula for situations when a mother is unable to breastfeed, and where alternatives including safe donor breast milk are not available.

- **Goal 12. Ensure sustainable consumption and production patterns** (*achieve sustainable production and use/consumption practices, reduce waste production/pollutant release into the environment, attain zero waste lifecycles, inform people about sustainable development practices*). Breast milk is the most sustainable nutrition for an infant. In comparison, infant formula, and to a lesser extent donor breast milk, carries a much higher pollutant release into the environment (e.g., through production of formula or pasteurization, bottling into typically single use plastics, and transport) .

### Potential Implications for Decisions

#### 1. *Individual*

- a. Parental decisions about whether to breastfeed and for how long
- b. Considerations around direct feeding vs. expressing milk
- c. Lifestyle choices such as diet, smoking, and alcohol consumption that can impact breast milk composition

#### 2. *Community policies*

- a. Access to health care and lactation specialists
- b. Good education to encourage a healthy lifestyle
- c. Assuring clear water, clear air, and safe spaces to feed or express milk

#### 3. *National policies*

- a. Assuring mothers are supported to enable prolonged breastfeeding
- b. Removing barriers to breastfeeding in public, including feelings of being marginalised and embarrassed
- c. Governance of formula milk marketing strategies that might discourage breastfeeding

### Pupil participation

#### 1. *Class discussion about ways that breast milk can support human health*

#### 2. *Pupil stakeholder awareness*

- a. What do you think can be done to encourage mothers to breastfeed?
- b. What more can be done to enable mothers to breastfeed and for longer durations?
- c. What are some ways we could improve health in infants who cannot be directly breastfed?

#### 3. *Exercises*

- a. Do you think formula milk should be provided by the state free of cost?
- b. Can you think of other ways a mother can pass microbes to their baby?

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- c. Should mothers be paid to donate surplus breast milk and what ethical considerations does this have?
- d. Formula milk is produced in large commercial facilities and relies on dairy farming. How might the sustainability of formula milk production be improved? And how might you improve on current bovine formula milk

### The evidence base, further reading and teaching aids

#### *Research teams websites:*

Neonatal Research (from the authors of this topic) - <https://www.neonatalresearch.net/>

THRiVE Discovery Lab - <https://www.thrivediscovery.ca/resources.html>

#### *Useful YouTube videos from reputable researchers*

CHILD Cohort Study: New scientific insights into breastfeeding - <https://www.youtube.com/watch?v=lfKKuwPpYWo>

Feeding Baby's Microbes - LET THEM EAT DIRT - feature documentary - [https://www.youtube.com/watch?v=P-jOW3W\\_Bqw](https://www.youtube.com/watch?v=P-jOW3W_Bqw)

### Glossary

Beneficial/commensal bacteria: Bacteria that are widely reported to be good and contribute positively toward health

Cytokines: Small proteins released by cells that have a specific effect on the interactions and communications between cells

Gut microbiome: Collection of microorganisms and their function in the gut

Human milk oligosaccharides (HMOs): Highly abundant non-nutritional component of breast milk that primarily act as 'prebiotics' (see definition below)

Immune system: Defense mechanisms that are either non-specific to the type of pathogen causing infection (innate immunity) and specific to certain pathogens (adaptive immunity). Inflammation is an example of an immune defense mechanism that in some instances can be damaging to the host.

Lactation: Process of producing and releasing milk from the breasts

Microbe: Shorthand for any microorganism, such as bacteria, fungi, and virus.

Pasteurisation: Heat treatment of milk to kill pathogens that may be found in the raw milk.

Pathogenic bacteria: Microorganisms that can cause disease

Prebiotics: Substrates that promote the growth of beneficial (i.e., good) bacteria.

Probiotic: A bacteria known to be beneficial (i.e., good)

Secretory immunoglobulin A (sIgA): The most abundant immunoglobulin in human milk which can protect infants from harmful pathogens