# Seeding Lifelong Health: The Impact of Pregnancy, Birth, and Infant Care on the Baby's Developing Microbiome
## Audio Transcription
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Cover Slide
Hello and welcome. This is Lori Nicholson with Joyful Birth HypnoBirthing®, and I'm happy to share this presentation with you, Seeding Lifelong Health: The Impact of Pregnancy, Birth, and Infant Care on the Baby's Developing Microbiome.

Disclaimer
A short disclaimer before we get started here. I am not a medical care provider, I'm a childbirth educator and a researcher by training. So nothing in this presentation should be construed as medical advice. Please seek medical care from your care provider. This presentation is informational in nature only.

Slide 3
(No text.)

Slide 4
So what exactly is our microbiome? Our microbiome is simply all of the organisms that live within and on us including bacteria, fungi, viruses, protozoa. And they live all over our body, in our intestines, our mouth, our vagina, on our skin. And truly, we need diversity in our microbes in order to be able to fight pathogens and stave off disease. So they're really integral to our lifelong health.

And there are certain things that can have a negative impact on our microbiome. Those include antibiotics and antimicrobial products. And our lifestyle and diet has really started affecting our microbiomes globally as well, because we've lost a lot of our microbes due to changes in our diets and the widespread use of antibiotics. So in response to this, in 2007, the National Institutes of Health launched the Human Microbiome Project in order to study how microbiomes may lead to various non-communicable diseases and what impact on our lifelong health our microbiomes and the changes in our microbes might be having on our lifelong health.

Slide 5
Why does our microbiome matter? Well, an unbalanced microbiome can lead to low grade inflammatory responses in our body, and actually can lead to "leaky gut syndrome" in children's intestinal linings. It can lead to an abnormal processing of food, and therefore, it can have long-term implications. It can lead to potentially chronic conditions later in life.

Slide 6
Several non-communicable diseases, in fact, have been associated with the poorly developed microbiome, such as allergies, asthma, celiac disease, irritable bowel syndrome, diabetes, eczema, mental health issues—perhaps even including autism spectrum disorder—necrotic enterocolitis in newborns, and obesity as well.

Slide 7
The next few slides highlight tables that were found in an excellent article on the development of the baby's microbiome, which is referenced here. And these factors can take place prior to birth, during or at birth, or even after birth. The factors that can really impact the colonization of the gut microbiota before birth include the intrauterine environment (which is no surprise at all) but also maternal stress, maternal antibiotic use, maternal smoking, and the length of the gestation can also impact how the baby's microbiome develops.

In addition, at birth, the mode of delivery is incredibly important, whether it's a C-section versus a vaginal delivery. And the environment in which the mother is giving birth also has a large impact on the baby's microbiome. The contact with the mother, since the microbes can develop on the skin, and contact with healthcare staff, for the same reason, the skin-to-skin contact, can have a really large impact on how the baby's microbiome develops.

After birth, the factors that can really impact the development include breastfeeding versus formula feeding; when the weaning happens and when food supplementation begins; antibiotic exposure; the home or family setting, whether it's a rural environment or an urban environment; and contact with siblings and other family members as well. Researchers have found that there is an inverse relationship between allergy prevalence and various measures of hygiene. For instance, growing up on a farm, experiencing early daycare, and coming from a lower-economic status household are all associated with healthier gut microbiota. Exposure to other siblings and to animals, particularly dogs, decreases the risk of later onset of allergic reactions and asthma. All of these factors play a large role in how the baby's gut health develops.

Slide 8
Let's take a closer look then at those factors that can influence the development of the baby's microbiome prior to birth. The intrauterine environment obviously has a large impact here through the presence of bacteria in the uterus, the amniotic fluid, or the meconium. And this can lead to antenatal infections such as urinary tract infections in the mother during the first trimester. And it can even contribute to preterm birth. Stress during pregnancy can lead to low counts of beneficial bacteria, which can lead to allergic reactions in the infant.

Probiotic use during pregnancy can have a positive impact on the baby's microbiome. It increases the colonization of beneficial bacteria and leads to an increased diversity in those bacteria and, therefore, can lead to a reduced incidence of allergic reactions later in life. Conversely, antibiotic use during pregnancy can delay colonization or reduce the abundance of beneficial bacteria and lead to increased allergic reactions such as asthma, allergic sensitization or allergic rhinitis, IBS, IBD, gut issues later in life for the baby. Smoking during pregnancy can lead to an increased risk of IBD as well.

  

Slide 9

Those factors that can impact the baby's developing microbiome at or during birth include the length of gestation and how the baby was born—whether it was a C-section or a vaginal delivery. Very low birth weight babies tend to have a very "sparse" microbiome compared to full-term infants because they often have experienced: C-section births, antibiotic exposure, prolonged stays in the NICU (and therefore, large exposure to antimicrobials), and formula supplementation. Preterm births, in fact, have been associated with a slow rate of bacterial colonization for the baby and reduced bacterial diversity, which can lead to NEC, necrotic enterocolitis; whereas, term births have a lower incidence of NEC because there's higher bacterial diversity and increased abundance of beneficial bacteria. C-section deliveries have been associated with reduced bacterial richness and diversity, reduced colonization by beneficial bacteria, and increased colonization by potential pathogens, which has been shown to lead to an increased risk of asthma, allergic reactions, Type 1 diabetes, atopic eczema, obesity, and NEC, so a large impact there; whereas, vaginal deliveries have been associated with a decreased risk of asthma and allergic reactions.

Slide 10

So the answer to why does the baby's developing microbiome matter is that we're laying the groundwork for the lifelong health of our children through the way in which we prepare our bodies for conception, care for our bodies during pregnancy, and birth our babies.

Slide 11

So how does the baby's microbiome develop? Well, researchers have found that human microbial colonization begins in utero and develops in a non-random way. In other words, the starting point of the development of the microbiome helps determine how the development will proceed and unfold.

The mother's gastrointestinal tract is the largest source of microbial exposure for the baby, which is why mothers-to-be should address their gut health *prior* to conception because the mother's gut health at conception is the starting point for the development of the baby's microbiome. So the health of that mother's gut at conception helps determine that child's lifelong health from the very beginning. In fact, one study—the Galley study (Galley et al. 2014)—found that maternal obesity is "associated with different microbial profiles in offspring 18-27 months of age." This relationship remained, even after accounting for paternal BMI and the child's body composition.

Slide 12

As you can imagine, prenatal nutrition is incredibly important in the development of the baby's microbiome. Our gut microbes impact our brain tissues and nervous system tissues through the brain-gut-enteric microbiota axis. In fact, researchers are speculating that brain plasticity may be dependent on the normal development of the microbiome, due to this brain-gut-enteric-microbiota axis.

The fetal microbiome and, therefore, the development of the baby's immune system depends on adequate maternal nutrition. One study found a reduction in gestational diabetes when women took probiotics early in pregnancy, although other studies have shown mixed results on the use of prebiotics and probiotics during pregnancy. Always consult your health care provider.

In terms of maternal nutrition, certain micronutrients and one fatty acid are especially important—folate and other B vitamins, iodine, Vitamin D, and DHA, which is an Omega 3 fatty acid.

Slide 13

Folate is necessary for normal fetal spine, brain, and skull development—thus protecting against neural tube defects like Spina Bifida—and it also helps control gene expression. Furthermore, it helps modulate epigenetic mechanisms that help the immune system to develop, which thus protects against allergic risk and asthma development.

Epigenetics refers to the external modifications to DNA that turn genes on or off. The modifications don't actually change the DNA sequence, but may change which aspects of the DNA are expressed. New research suggests that prenatal folic acid supplements may lower the risk of severe language delay, autistic disorder, and autism spectrum disorders as well.

You can get a good supply of folate through dark green vegetables—eating vegetables like broccoli and spinach—and also dried legumes, such as chickpeas, beans, and lentils. Some countries fortify cereals, flours, cornmeal and/or pastas with folic acid. Pregnant American women are generally counseled to take a folic acid supplement during pregnancy.

Slide 14

Iodine is essential for thyroid hormone production, and the production of the thyroid hormone is necessary for normal brain and nervous system development and also modulating immune system response. Iodine is related to the prevention of mental retardation, and you can get good sources of iodine through eating sea vegetables, cranberries, organic yogurt and cheese, as well as strawberries.

Slide 15

Vitamin D not only helps maintain the pregnancy, but it also lowers the risk of preeclampsia. And it's crucial in the skeletal and brain development and the development of the immune system of the baby. It helps to regulate antimicrobial innate immune responses, can inhibit lymphocyte proliferation, and can decrease the risk of RSV infection during the infant's first year of life, which is really important. Current animal research implies that it may decrease the risk of neurodevelopmental disorders as well. Vitamin D can be found in foods such as fish, fish oils, mushrooms, beef liver, cheese, milk, and egg yolks. It's also known as the sunshine vitamin. So just getting outside and getting a bit of sunshine—not too much, just so your skin gets a little bit of sun exposure without burning—that's an important thing that you can do for yourself as well.

Slide 16

The omega-3 fatty acid known as DHA is necessary for some membrane formation in the brain and central nervous system which helps to ensure proper fetal growth. It also prolongs gestation in high risk pregnancies. It's associated with increasing the baby's birth weight, head circumference, and birth length as well, and it enhances baby's visual acuity, hand-eye coordination, attention processing, problem solving ability, information processing, and neurological outcomes. You can get DHA through foods such as algae, fatty fish, liver, fish oil and egg yolks.

Slide 17
The intrauterine environment and the environment in which the baby is born—whether the baby's born at home, in a birth center, in a hospital—and the people with whom the baby comes in contact all help to form the baby's microbiome. These early exposures impact the intestinal microbiota of the baby. They train the baby's immune system.

Remember, we talked before about how the microbiome develops in a non-random way, and the starting point helps determine how the microbiome will develop. The baby's brain tissues and nervous system tissues are dependent upon the seeding and diversity of microbes in the gut. And therefore, the exposure to pathogens and/or the lack of exposure to beneficial microbes are associated with those childhood diseases that may persist into adulthood that we discussed earlier.

The greatest challenges to the healthy development of the baby's microbiome are: Cesarean delivery; antibiotic exposure before, during, or after birth; and formula-feeding.

Slide 18
If you're interested in the microbiome and you haven't yet seen the film *MicroBirth*, I recommend that you go out and you get yourself a copy. It is fantastic, and it was my introduction to this topic. It's excellent. According to the experts that were interviewed for this documentary, *MicroBirth*, there are three crucial steps in the formation of an infant's healthy microbiome. Step one is to have a healthy vaginal birth. Step two is immediate skin-to-skin contact with the mother following birth. And step three is exclusive and even extended breastfeeding for at least six months or more.

Slide 19
This slide shows a visual model of the development of the healthy microbiome, showing that vaginal birth followed by skin-to-skin contact with the mother, followed by breastfeeding is what really helps set the baby's healthy microbiome in process.

Slide 20
We'll start by talking about vaginal birth and its impact on the development of the baby's healthy microbiome.

Slide 21
We've already discussed epigenetics and how the expression of certain genes can be turned on and off during certain periods of our lives. And birth is one of those major programming events where genes can be switched on and off. So it's really important that we approach our births consciously.

Key bacterial species gather in the mother's vagina and the breasts in the days leading up to the birth, and the baby acquires the mother's bacteria while coming down the birth path and swallowing amniotic fluid. This is the major seeding event for the infant's gut microbes, which are crucial to the development of the child's immune system. Disrupting this major seeding event due to a C-section delivery may increase the risk of asthma, allergies, Type 1 diabetes, eczema, and obesity in the baby.

Of course, there are always going to be emergency C-sections. I'm talking about being more conscious about not scheduling elective C-sections. Also, using antibiotics during birth may have a much greater impact genetically than using antibiotics at other times during your life, so really being conscious and aware of the choices we're making during our births. It's really important for the lifelong health of our kids.

<u>Slide 22</u>
Let's talk a little more about Cesarean birth. From the perspective of the microbiome, babies born via C-section are not getting the seeding of their immune system that they require. They have less diverse and less rich gut microbiota than vaginally delivered babies. And it can be difficult for their immature immune systems to determine which bacteria are good and should be tolerated, and which are harmful and should be attacked.

Induction, antibiotics, Pitocin, C-section, forceps, all of these interventions may change the baby's epigenome. The baby's metabolism may not stabilize. The baby's immune system may not mature, or it may be considered "incomplete." And researchers have found that if an individual has one non-communicable disease early in life that that individual is at a greater risk for other non-communicable diseases later in life.

This is an association. It's not causation, but it's important to keep in mind so that, again, we are thoughtful of our birth choices.

<u>Slide 23</u>
One set of researchers have, in fact, created an immunological model that they call "The Completed Self." And the Completed Self, they say, forms in the neonate. So prenatal and perinatal protection of the development of the Completed Self is crucial. Three major components affect the formation and integrity of the Completed Self: number one, useful epigenetic programming; number two, effective immune development; and number three, complete microbiota acquisition.

So, will the child's microbiome become complete, leading to a life of health? Or will the child's microbiome remain incomplete, leading to a life of disease? And the answer to this question lies in the actions that the mother-to-be takes—her prenatal nutrition, her gut microbiota health, her own microbiome, because the baby, remember, is inheriting his or her microbiome from the mother.

<u>Slide 24</u>
If a baby needs to be born via C-section, that doesn't necessarily mean that the infant's microbiome is going to be ruined. There are ways in which you can seed the baby born via C-section. And these seeded babies look more like vaginally-born babies than like C-section babies from the perspective of the microbiome.

Dr. Maria Gloria Dominguez-Bello, who's an associate professor at New York University, provides an overview in the *Microbirth* documentary about how to go about seeding babies born via C-section—how you can incubate sterile gauze in the mother's vagina for an hour prior to birth, extract the gauze before the C-section and then expose the newborn to the vaginal gauze after the C-section birth. Again, I highly recommend that documentary. It's wonderful. In fact, Dr. Dominguez-Bello and her colleagues just published the results of a small, pilot study in the journal *Nature Medicine* where they used the "seeding" technique to swab four Cesarean-born babies with their mother's vaginal microbes immediately following birth, and they found a partial restoration of the microbiota of these infants from the vaginal microbial transfer. Specifically, they found that the gut, oral, and skin bacterial communities of these swabbed infants were more similar to their mothers and to vaginally born infants than unswabbed C-section infants. However, the transmission was not complete, in that *Lactobacillus* was not maintained on the skin of the swabbed infants after 30 days, and the anal bacteria of these infants were lower in abundance than those of vaginally born infants. Still, the transfer technique was partially successful. Obviously, additional studies need to be done on larger samples to get a true sense of the potential of this process, but this study is a promising beginning. As a reminder, please do not take this as medical advice. This is for informational purposes only.

If babies are born via C-section, they should have the benefits of immediate skin-to-skin contact with the mother, though, because that can really help in the development of their microbiome.

<u>Slide 25</u>
When the baby is born, he or she is seeded with not only the mom's microbes but also the microbes in the environment in which they're born. As discussed, the foundation for baby's long-term health is laid at this time during birth, and we have no research as of yet to inform what impact different birthing environments may have on the baby's microbiome. However, being in one's home environment may support this seeding process, exposing baby only to his or her own family's microbes.

Babies born in a hospital or birthing center may benefit from being exposed only to those items that have been brought from home, such as blankets and clothing, immediately following birth. So especially for those babies who need to be born via C-section, making sure that the other components of a healthy microbiome are in place—immediate skin-to-skin contact with the mom, breastfeeding, and exposure to the family's microbes through blankets and clothing brought from home—are very important. This is, of course, also important for the vaginally-born baby. So again, being conscious about the choices around your birthing and about who and what touches your baby immediately following birth is very important.

<u>Slide 26</u>
Antibiotic exposure can really wreak havoc on the baby's developing microbiome. Antibiotic use early in life has been associated with: increased IBD diagnoses, increased risk of diabetes, childhood asthma, and a 30% higher risk of developing multiple sclerosis (MS). Some researchers have even gone so far as to suggest that it may become necessary to take fecal samples of children prior to placing them on antibiotics, in case they ever need to recover beneficial microbes through a fecal microbial transplant later in life.

  

One small study examined the gut microbiota of nine newborns who were given IV Ampicillin and Gentamicin within 48 hours of birth. And these antibiotics were given directly to the babies. The researchers did not look at the infants' gut microbiota as a result of the mother receiving IV antibiotics during labor, for instance.

Then four weeks and eight weeks after the infants completed their antibiotics, the infants' stool samples were compared to the stool samples of nine untreated infants. At four weeks after completing the course of antibiotics, the treated infants had significantly lower levels of beneficial bacteria, significantly higher levels of proteobacteria, and less diversity of their gut microbes.

<u>Slide 27</u>
By eight weeks, the treated infants still had significantly higher proteobacteria levels. They had recovered some of the levels of the other strains of bacterium such that they were, therefore, similar to those in the control samples, again, by eight weeks. And yet there were still fewer different types of Bifidobacterium species present. So they had less diversity still in their stool samples.

The authors concluded that the combined use of Ampicillin and Gentamicin in early life can have significant effects on the evolution of the infant gut microbiota, the long-term health implications of which remain unknown. We really don't know. We know that there's an association between antibiotic exposure and the baby's developing microbiome and possible non-communicable diseases as a result of that antibiotic exposure. But the true scope of this is still rather unknown.

<u>Slide 28</u>
Let's talk now about maternal antibiotic usage during labor and its impact on the baby's developing microbiome. When women are given antibiotics during labor, it is often because they have tested positive for Group B Strep or GBS, a common bacterium carried in the intestines or lower genital tract. Nobody really knows exactly how many women are carriers of GBS, but the estimates are that 12 to 27% of pregnant women worldwide are colonized with GBS—meaning they carry it in their bodies, but are not harmed by it.

However, it can do great harm to their infants. GBS can cause life-threatening illnesses and complications in infants, including: inflammation of the lungs, inflammation of the membranes and fluid surrounding the brain and spinal cord, infection of the bloodstream, and even death.

<u>Slide 29</u>
Just because babies are exposed to GBS in the birth path, does not mean that they will develop a GBS infection. Those are two very different things. The standard of care for GBS-positive women during labor is multiple doses of IV antibiotics administered four hours apart. And the good news is that IV antibiotics have been shown to be protective for the babies when exposed to GBS.

In clinical trials, the risk of early GBS infection dropped by 83% when antibiotics were administered to the mother during labor. However, the issue is we do not understand the long-term impact of this antibiotic exposure on the baby's developing microbiome. So researchers are seeking alternatives. Currently, researchers are starting to look at maternal probiotic usage during pregnancy to see if that can keep GBS colonization from being present during the labor and birth.

Slide 30
Three studies have found that probiotics can strongly inhibit the growth of GBS in vitro in a Petri dish, thus supporting probiotics as a potential preventative for neonatal GBS infections. Other research has found that prenatal probiotic therapy has the potential to reduce GBS colonization, but that the intervention is correlated with daily adherence to taking the probiotic regimen. In other words, those who took their probiotics regularly had lower levels of GBS colonization than those who skipped days of taking their probiotics. So adherence to the regimen is very important.

Slide 31
Another small clinical trial found that non-pregnant women were able to increase the level of *Lactobacilli* in the vagina from wearing panty liners saturated with probiotics. The women who had higher levels of *Lactobacilli* in the vagina also had lower levels of GBS. Now, that's among a non-pregnant population, obviously, but it's intriguing.

Fortunately, a large clinical trial is underway at Stanford University to "determine if oral probiotic supplementation during the second half of pregnancy decreases maternal GBS recto-vaginal colonization at 35 to 37 weeks gestational age, thereby decreasing the need for maternal antibiotic administration at the time of labor." So I eagerly await the outcome of that study, and I'm happy to see that researchers are looking at alternatives that will both protect the infant during birth and also protect the infant's developing microbiome for lifelong health.

Slide 32
We've now seen how vaginal versus C-section birth can impact the baby's developing microbiome, as well as how the exposure to antibiotics can have an impact. Now let's move on to skin-to-skin contact and see how that impacts the baby's developing microbiome.

Slide 33
Immediate skin-to-skin contact, sometimes referred to as "kangaroo care," is the second crucial step in developing a healthy microbiome. And as one researcher has pointed out, "Separation of human mothers and newborns is unique to the 20th century." And it's different from how mammals operate in nature.

Kangaroo mother care includes three major components. It includes: skin-to-skin care or contact; frequent and exclusive, or nearly exclusive, breastfeeding—preferably exclusive; and treating the mother and baby as a dyad, what is sometimes referred to as couplet care.

Slide 34
It's interesting to ponder why, when researchers study human mother/newborn contact, keeping mothers and babies together is always considered the experimental intervention. And yet, in nature, when researchers study non-human mammals, the experimental intervention is separating the newborns from their mothers. We are programmed to want to be with our mothers. That is

the default safety mechanism of survival. So something has really shifted, and perhaps gone wrong, with our healthcare system such that we think it’s unusual for mothers and babies to be kept together. That is actually the norm.

Slide 35

Immediate skin-to-skin contact is so important for the infant and mother. Neuroscientists believe that the newborn period is a “sensitive time” that meets the mom’s and baby’s biological needs, helping program physiology and behavior for the future. They’ve also found that skin-to-skin promotes neurobehavioral development, infant temperature stabilization, less infant crying, higher infant blood glucose, increased maternal satisfaction and confidence, and an improved breastfeeding relationship.

Slide 36

When the baby is born, immediate skin-to-skin from the mom/baby dyad following the birth leads to skin-to-skin transfer of skin bacteria to the baby. Baby has to get his or her microbes from somewhere, so we want the baby’s immune system primed with the right type of bacterium. As discussed earlier, this impacts the choice of birthing environment or birthing facility as well. This is when the baby’s immune system learns what is friend versus what is foe, and scientists believe the microbes have one chance to do this: during birth and immediately thereafter. You can correct the balance of microbes with probiotics later in life, but you cannot retrain the immune system, so this is incredibly important.

Slide 37

As we’ve discussed, C-section births can really impact the unfolding of the baby’s developing microbiome. And because C-sections are getting safer, the threshold at which OBs and women are willing to resort to C-sections is getting lower and lower. It’s becoming more and more common. Yet, the outcomes of C-section birth can be allayed somewhat through immediate skin-to-skin care between the mom/baby dyad. In fact, that can have a huge impact on the healthy development of the C-section baby’s microbiome.

Yet, in 2009, only 32% of U.S. hospitals implemented skin-to-skin care for most mother/baby dyads within two hours of an uncomplicated C-section. Changing this process, this procedure in hospitals, can have a huge impact on the lifelong health of those babies who have had a C-section birth.

Slide 38

Interestingly, babies born vaginally have a microbial profile resembling their mother’s vagina; whereas, babies born via Cesarean acquire their first microbes from the skin of people who contact them, preferably a parent, but sometimes a care provider. C-section babies tend to have microbiota more associated with the skin than with the gut or vagina, which may lead to less diverse and less rich gut microbiota and, thus, a less robust immune system overall. However, again, these outcomes can be ameliorated somewhat by offering the C-section baby that immediate skin-to-skin care with mom and also exposing the baby to only clothing and blankets brought from home, since those objects will have the family’s microbes all over them. Those steps will help seed the baby appropriately as well.

Slide 39
The third crucial step in helping seed a healthy microbiome for the baby is breastfeeding. For mothers who cannot breastfeed, several other options are available including: using donor milk; or using formulas fortified with prebiotic and probiotic compounds.

Slide 40
Breastfeeding is the postnatal method for mother/baby microbial exchange. It seeds and selects for particular populations of bacteria. In addition, breast milk has anti-inflammatory hormones, antibodies, and sugars, which are indigestible by the baby. What's interesting is those sugars are eaten by the good bacteria that are newly seeded in the baby's gut. In other words, breastmilk helps the good bacteria thrive. It's pretty amazing.

By the end of the baby's first year, the baby's microbiome has become more complex and stable. The child's microbiome will be similar to an adult's microbiome by three years of age. So in other words, the child's microbiome, at three years old, is likely to be that individual's lifelong signature of microbiota. Those first three years are crucial.

Slide 41
One study found that the microbiota in breast milk differed between women who delivered vaginally versus those who had had an elective Cesarean. And another study observed more than two times more good bacteria cells in breastfed infants compared to formula-fed infants. Breast milk is very high in prebiotics, and it selects the beneficial bacteria and limits the colonization of harmful ones.

It's been found that even in very small amounts, formula given as a supplement while breastfeeding can alter the structure and relative abundance of bacterial communities in the breastfed infant's gut. For instance, bacteria associated with energy resorption and obesity were more abundant in formula-fed infants than in breastfed infants. So exclusive breastfeeding is preferred. Exclusive breastfeeding has also been found to help restore bacterial abundance in previously formula-fed infants. So that's wonderful to know that the baby's gut health can be improved with exclusive breastfeeding, even if formula has been given previously as a source of feeding.

Slide 42
One very interesting finding is that breast milk may provide the baby's gut microbiome with greater plasticity to ease the transition into solid foods. The timing of the introduction of solid foods, the type of solid foods that are consumed, and certain nutrients such as iron and fatty acids, all influence the diversity and composition of the infant's gut bacteria. There's very little information on how dietary composition or nutrient intake affects the microbiome of children and the health consequences of differences in the gut microbiome. However, there's a new project that's been started entitled "Breast Milk, Gut Microbiome and Immunity Project." The researchers are looking to discover new ways to promote healthy growth in infants and children through studying the development of the microbiome. So again, I eagerly await the outcomes and results of these studies.

Slide 43
If you're interested in learning more about the microbiome, there's lots of information out there. The American Microbiome Institute has a wealth of information, as does Gut Microbiota World Watch, which is a European group. There's an entire journal devoted to the microbiome called *Microbiome* and, of course, there's the NIH Human Microbiome Project. Those links are listed here for your benefit.

Slide 44
We've covered a lot of ground in this presentation. So let's go ahead and summarize what we've learned about the development of the baby's microbiome. First, we need diversity in our microbes in order to fight pathogens and stave off disease. They're integral to our immune and metabolic health. And human microbial colonization begins in utero and develops in a nonrandom way. In other words, the baby inherits the microbiome from the mother. This seeding of microbiota that the baby receives from his or her mother trains the baby's immune system.

Slide 45
The fetal microbiome and, therefore, the entire development of the baby's immune system depends on adequate maternal nutrition. The mother's intake of the micronutrients folate, iodine, and vitamin D as well as the fatty acid DHA is especially important. An unbalanced microbiome has been associated with several health challenges including asthma, eczema, diabetes, and obesity in the child.

The greatest challenges to the healthy development of the baby's microbiome are: Cesarean delivery; antibiotic exposure before, during, or after birth; and formula feeding. And therefore, the most important steps that can be taken to ensure the proper seeding of the baby are: step one, vaginal birth; step two, immediate skin-to-skin contact with the mother following birth; and step three, exclusive breastfeeding, preferably for at least six months.

Slide 46
Remember that the baby acquires the mother's bacteria while coming down the birth path and swallowing amniotic fluid. Vaginal birth is actually the major seeding event for the infant's gut microbes which are crucial to the development of the child's immune system. Disrupting this major seeding event due to a C-section delivery may increase the risk of asthma, allergies, Type 1 diabetes, eczema and obesity in the baby.

From the perspective of the microbiome, babies born via C-section are not getting the seeding of their immune system naturally that they require. It is possible to seed the baby born via C-section immediately following birth, though. These seeded babies look more like vaginally born babies than like C-section babies from the perspective of the microbiome. In fact, for those babies born via C-section, using the seeding process via vaginal swabbing, plus using immediate skin-to-skin contact with the mother, plus practicing extended breastfeeding for six months or more will all help establish the baby's healthy microbiome.

Slide 47
Following vaginal birth, the second crucial component in the establishment of a healthy microbiome is skin-to-skin care. Immediate or very early skin-to-skin care has both physiologic

and psychologic benefits to the mother/baby dyad at a very sensitive developmental time for both bonding and the development of the microbiome.

Early skin-to-skin care has a positive effect on breastfeeding, respiration, blood glucose, and lessened crying for the babies, while also leading to less breast engorgement and anxiety for the mothers—all with no apparent short- or long-term negative effects. Skin-to-skin care may be even more important for low birthweight babies than for normal babies, as it leads to lower rates of mortality, sepsis, hypothermia, severe illness, and respiratory problems, and decreases hospital stays, while assisting those low birthweight babies with better growth, breastfeeding, temperature regulation, and bonding with their mothers.

Skin-to-skin care is the second stage in the all-important development of the baby's microbiome and thus the baby's immune system for life. There's no do-over for this critical contact.

<u>Slide 48</u>
We know that breastfeeding is extremely beneficial in both the short-run and the long-run to both babies and their mothers. This is widely known, and it's also the third crucial step in helping the baby develop a healthy microbiome. It's rich in prebiotics and it selects for the persistence of beneficial bacteria, while limiting the colonization of harmful bacteria. In addition, breast milk may provide the gut microbiome with greater plasticity to ease the transition into solid foods.

<u>Slide 49</u>
If I were the baby who wanted to be conceived, what would I want in terms of the development of my healthy microbiome? Well, I would want my mom to be of healthy weight, with a good healthy microbiome herself prior to conception. One research study found that maternal obesity led to "significant effects on the composition of the gut microbiome of offspring" especially among those of higher socioeconomic status (Galley et al. 2014). I would want her vaginal microbiome rich in *Lactobacilli* which is typically found in normal healthy pregnancies. I would want my mom following good nutritional guidelines, eating fermented foods and those with live cultures that are especially good for gut health. I would want her following the micronutrient and fatty acid recommendations. I would want her exercising regularly, being a nonsmoker, and having low stress levels. In fact, in one study, infants whose mothers were anxious in pregnancy (based upon self-report and clinical evaluations) exhibited poorer adaptive immune response at 6 months of age (O'Connor et al. 2013). Essentially, I want my mom to be healthy in mind, body, and spirit—creating a welcoming environment for me in which I can be conceived.

<u>Slide 50</u>
As the baby who has already been conceived, I want to experience a vaginal birth where I will be seeded with my mom's healthy microbes. I want to experience birth without the use of any antibiotics or other interventions. I want to be born at home in my family's bacterial environment and to have only blankets or clothes from that environment touch me.

Once born, I want to experience immediate skin-to-skin with my mom and no separation from mom. I want care providers to do any newborn checks while I am experiencing skin-to-skin care with my mom. Hands off from care providers as much as possible. I want my mom to exclusively breastfeed me for six months, at which time I will be introduced to solid foods.

And I want my mom to continue breastfeeding me from six months up to two years of age (or even longer) as I also eat solid foods. This is the recipe for helping infants develop healthy microbiomes.

<u>Slide 51</u>
The last 11 slides in this presentation are references for your use and future research. Here's to helping the next generation of babies develop healthy microbiomes, thereby seeding lifelong health. I'm Lori Nicholson. Thank you so much for joining me.