Development of the Neonatal Skin Microbiome

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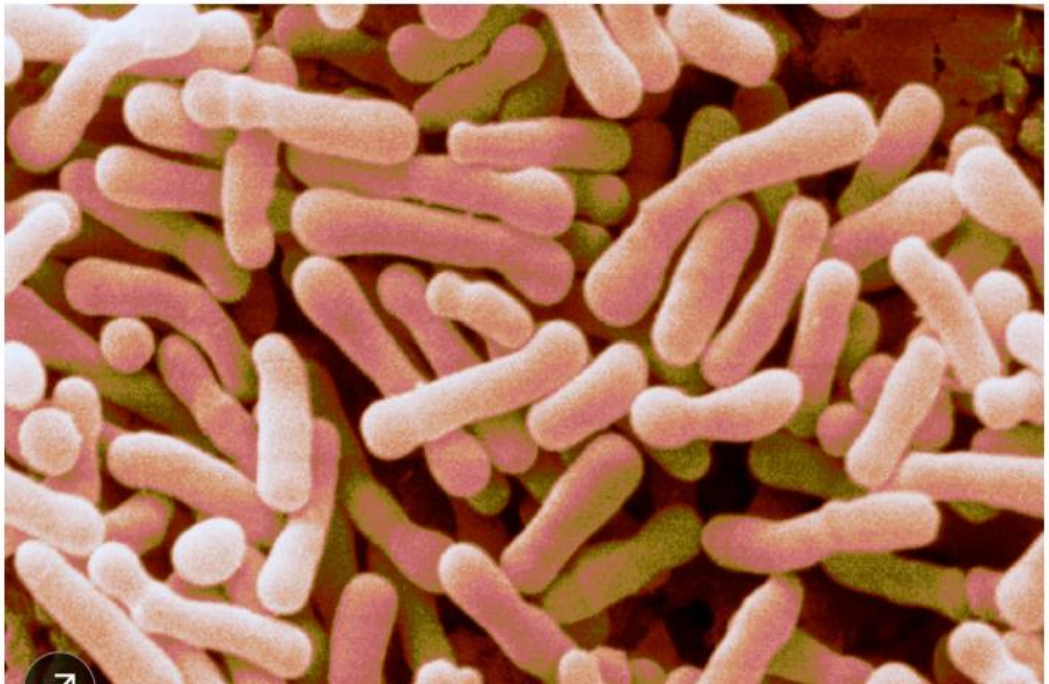
Human Microbiome Project

In 2008, the National Institutes of Health launched the Human Microbiome Project to characterize the human microbiome and analyze its role in health and disease.

MICROBIOME

Collectively, the resident microbes living on and within our body is known as our Microbiome

- Bacteria or Microbes are 10 times more prevalent than the human cells of our body.



Bacterial Benefits

- Hosts derive many benefits from their bacterial guests:
  - Development of Immunity
  - Protection from diverse pathogens
  - Biorhytms and Brain function
  - Vitamin synthesis: Bacteroides species in the colon synthesize our required Vitamin K
  - Digestion

Colonization of the Skin

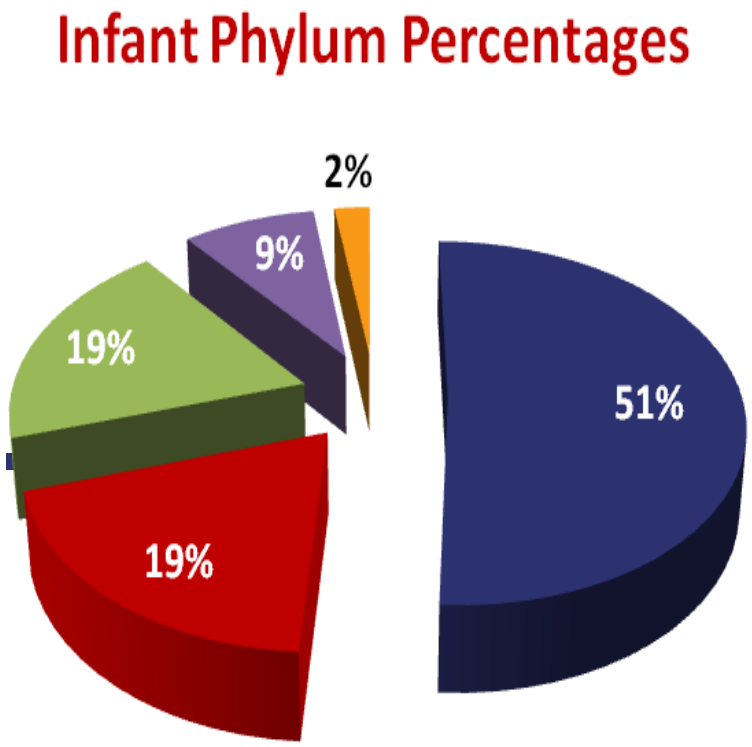
- The past decade has seen a shift in how we see the microbes and viruses in and on our bodies
- A few microbes make us sick, most are commensal (“good bacteria”)
- Imbalance of commensal bacteria may lead to disease states
- Determining the “microbiome” of our skin, GI, oral, vaginal and respiratory tract involves DNA sequencing, PCR techniques

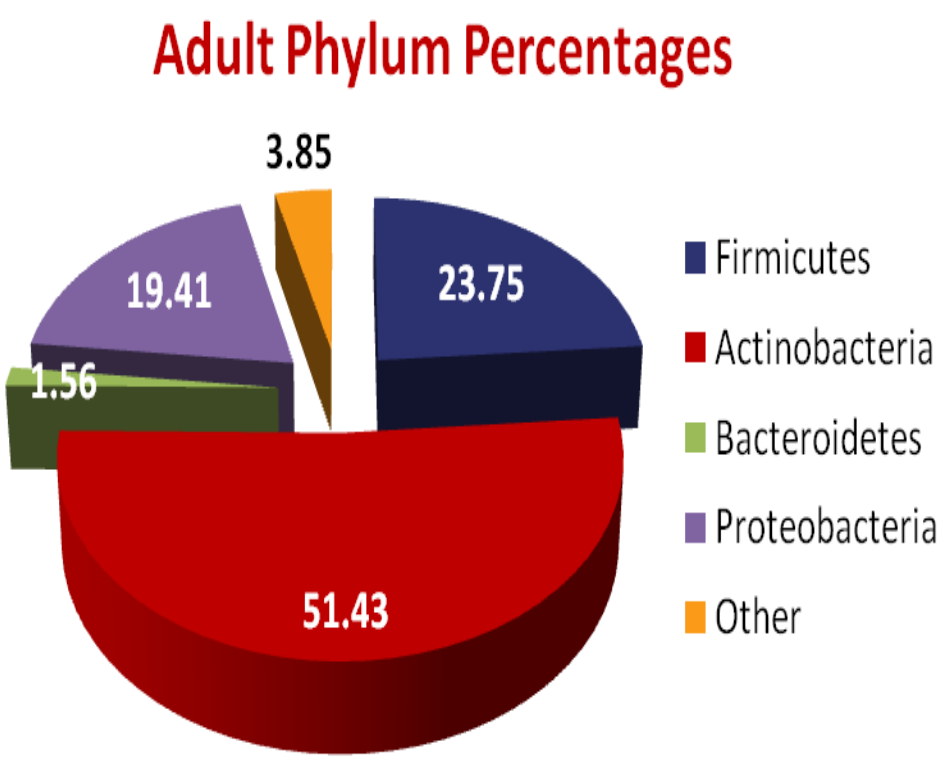
Diversity of the Human Skin Microbiome Early in Life

Capone K., et al (2011) J Invest Derm; doi:10.1038/jid.2011.168

- PCR microbiome: skin swabs from 31 infants (1-3, 4-6, 7-12 months); arm, forehead, buttocks
- Regional differences emerge after one month
- Infant skin: Firmicutes predominate (staph, strep, propionbacter)
- Adult skin: Actinobacteria predominate (gram + organisms, mycobacteria, corynebacteria)
- Healthy skin microbiome may have role in denying access to infectious microbes, help to modulate inflammatory responses.

Infant Skin Has Same Phyla of Bacteria, Represented in Different Proportions, Compared With Adult Skin





S. Epidermidis: Friend or Foe?

- Member of resident microflora
- Produces peptides that are toxic to other organisms (S. aureus, group A Strep)
- “Primes” keratinocytes to be able to respond more effectively and efficiently to pathogens
- Removing *S. epi* eliminates endogenous peptides, allows pathogens to colonize skin more effectively

Innate Immunity of Skin

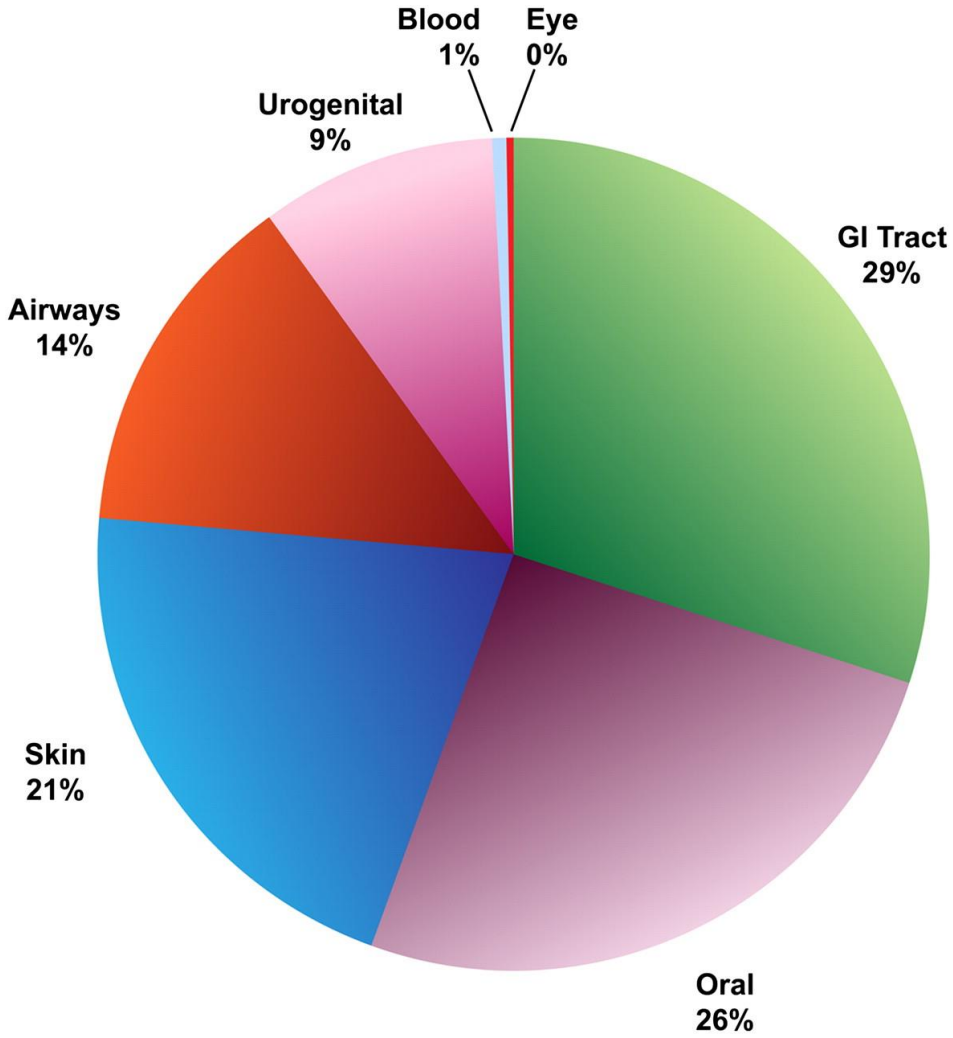
- Symbiotic relationship between skin and skin flora
- Skin provides sebum (lipids), sweat (minerals), keratin (protein) to resident flora
- Resident flora strengthens the skin's first defense (acid mantle) by producing anti-bacterials which compete and prevent colonization with harmful bacteria

➢ Antimicrobial defense system in the skin is more than just a mechanical barrier

50% of Species in Microbiome can not be grown in Culture

- 44 species living on the forearms
- 19 species in the fold behind the ears
- 2,368 species that dwell in the human navel according to the Belly Button Biodiversity Project

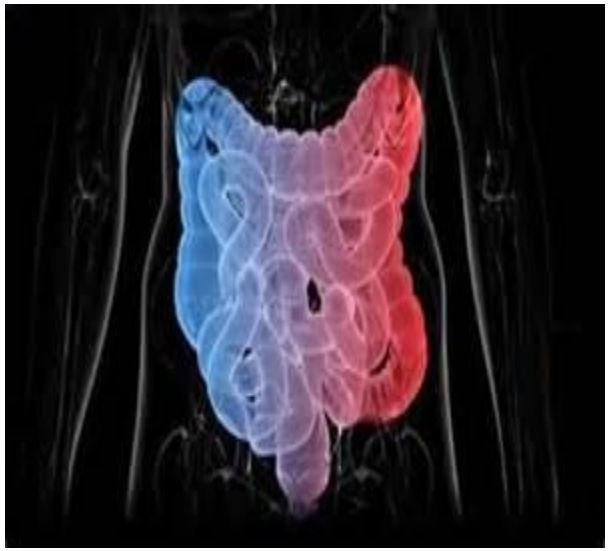
Bacterial distribution by body site.



The NIH HMP Working Group et al. Genome Res. 2009;19:2317-2323

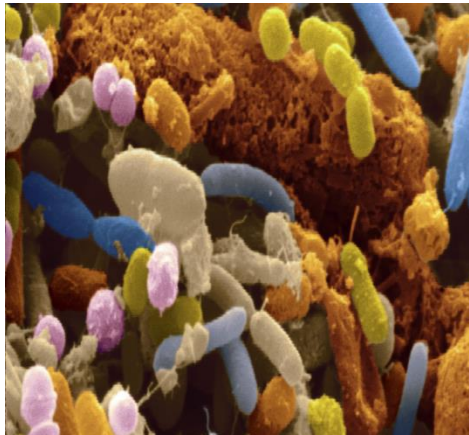
“Evidence exists that early colonization of the infant gastrointestinal tract by microbes is crucial for the overall health of the infant”

Teagasc. “Improving the infant gut microbiome.” Science Daily, 17 March 2011.



Intestinal Bacteria

- promotes development of the gut's mucosal immune system
- plays an important role in the postnatal development of the systemic immune system
- stimulates the production of antibodies to pathogens by the gut-associated lymphoid tissue
- aids in reducing an over-reactive immune response
  - -as in autoimmune disease and allergies
- aids in digestion and absorption of foods



Brain-Gut Microbiota signaling

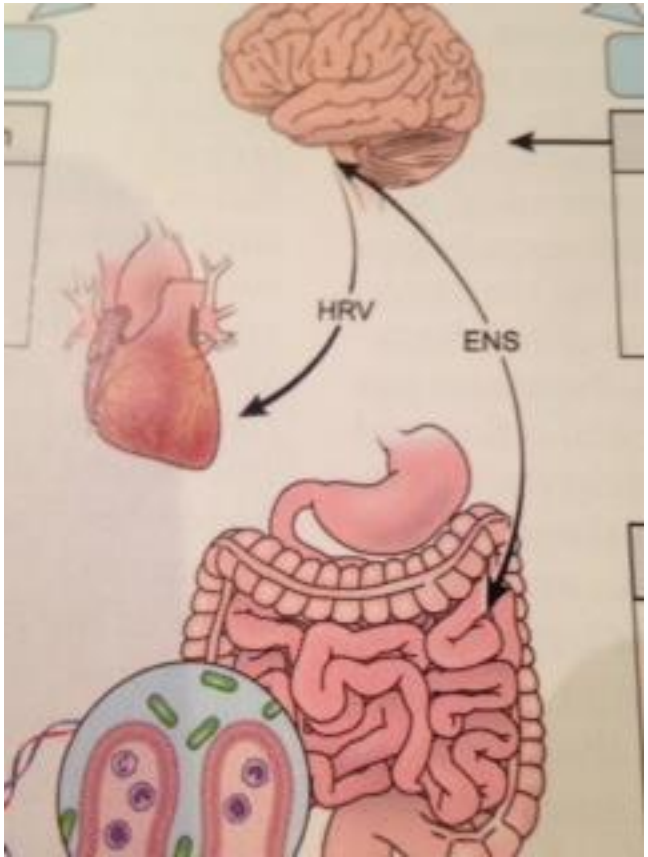
- Bottom-up – alterations in gut microbiota affect a variety of social and emotional behaviors.

- Top-down – stress activates cortisol which leads to increased gut permeability & the crossing of bacteria through the epithelial barrier and alters the microbiome

Brain-Gut-microbiota signaling

Communication between CNS & GI tract:

- Regulates stress & pain responses
- Cognition & behavior
  - Depression
  - Autism
  - Anxiety



- Cong et al, Advances in Neonatal Care, 2015

Maternal Microbiome

- Preterm Birth – risk influenced by vaginal microbiome, primarily Lactobacillus
- Oral peridontal disease linked to Pre-eclampsia and preterm birth
- Cardiometabolic Complications: Gut bacterial endotoxin implicated in Gestational Hypertension, Gestational Diabetes and Gestational weight gain

Maternal Microbiome in Preterm birth

New study links preterm birth with microbes in mom's body:

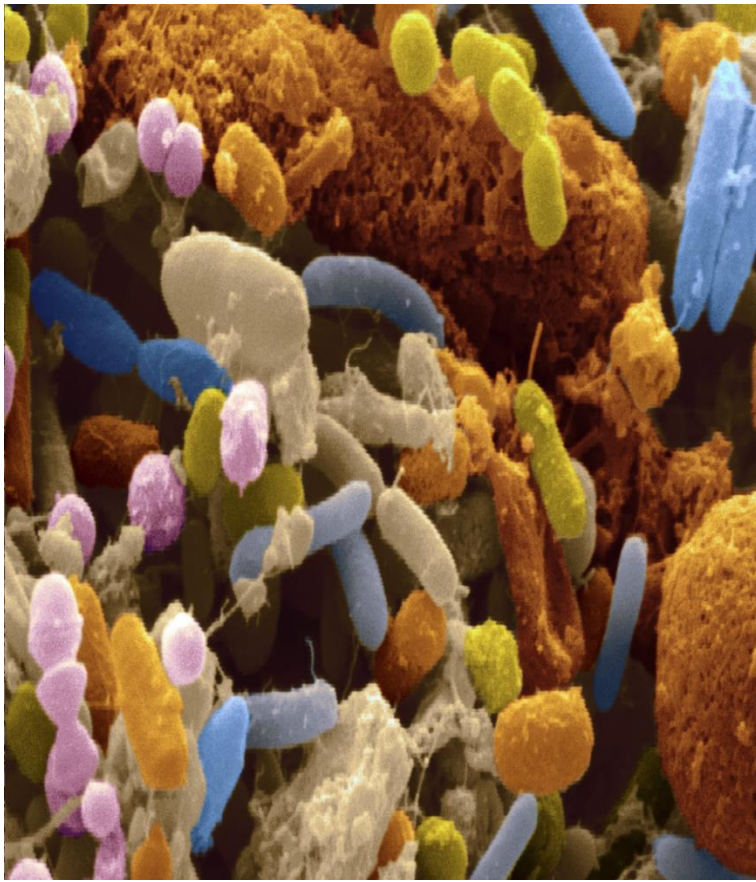
- 49 women; 15 delivered prematurely.
- Low levels of Lactobacillus in the women who delivered prematurely.

- Proceedings of the National Academy of Sciences

Newborn Intestinal Colonization

Current research shows that a baby seeds their gut from 4 sources:

- placenta during pregnancy
- birth canal during vaginal birth
- mother's skin from skin-to-skin contact
- breastfeeding



Vaginal Delivery

Exposure to Vaginal Microflora

Normal microbial "seeding" of GI tract

Normal development of immunity

C-Section Delivery

Lack of Exposure to Vaginal Microflora

Abnormal microbial "seeding " of GI tract

Abmormal development of immunity

Delivery Mode Shapes Initial Microbiota in Newborns

Dominguez-Bello M et al (2010) PNAS 107:11971-11975

- 9 mothers, 10 newborns
- 4 vaginal birth, 6 C/S

  Mother's skin, oral mucosa, vagina sampled 1 hour prior to delivery

  Neonates skin, oral mucosa, nasopharyngeal sampled <5 minutes after delivery, meconium <24 hours after delivery
- Found difference in microbial communities based on Delivery mode

Birth Route

- During vaginal birth, contact with the mother's vaginal and intestinal flora colonizes gut
- During cesarean delivery, contact of the newborn's mouth with vaginal and intestinal microbiota is missing

  -non-maternally derived bacteria

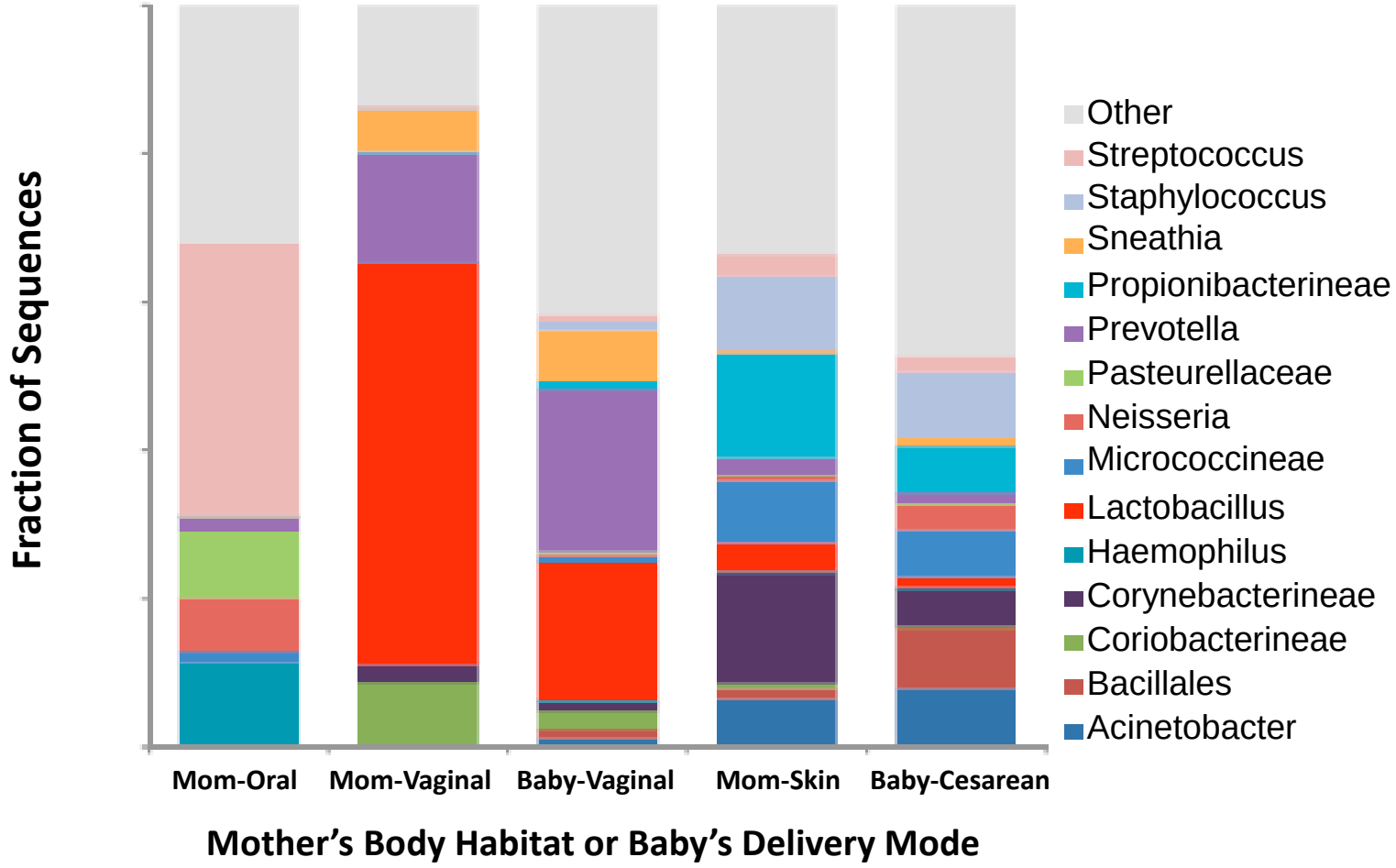
  -less diverse flora seen

  - delayed intestinal colonization

  -dominated by skin surface Staphylococus

Delivery Mode Shapes Initial Microbiota in Newborns

Dermal Microflora Transmission From Mother to Baby At Birth Correlates With Region of First Maternal Contact



Dominguez-Bello MG, et al. *Proc Natl Acad Sci USA* 2010;107:11971-11975

C-Section Babies Differ

- C-Section babies had increased rates of:
  - Obesity
  - Asthma
  - Allergies
  - Type 1 diabetes
  - Food allergies
  - Eczema
  - Celiac disease
  - MRSA Infections
  - Gastroenteritis

**Link found between Cesarean delivery, disturbed intestinal colonization and NEC

- Hallstrom et al 2004. Eur J Clin Microbiol Infect Dis 23(6):463-70

Infant Gut Microbiota

"Method of delivery (vaginal birth vs. cesarean section) and feeding practices (breastfeeding vs. formula feeding) influence the development of gut bacteria in newborns and thus may affect lifelong health"

Azad, Konya, Maughan et al. Gut microbiota of healthy Canadian infants: profiles by mode of delivery and infant diet at 4 months. Canadian Medical Association Journal, 2013.

Immune Development

- Gut flora in infants may be disturbed for up to 6 months after C-section delivery
- Postnatal development of the immune system may also be different; if intestinal flora develops differently depending on the mode of delivery
- After Cesarean delivery: type 1 diabetes, food allergies, celiac disease and atopic diseases are seen more often.

Gut Microbiome in Preterm Infants

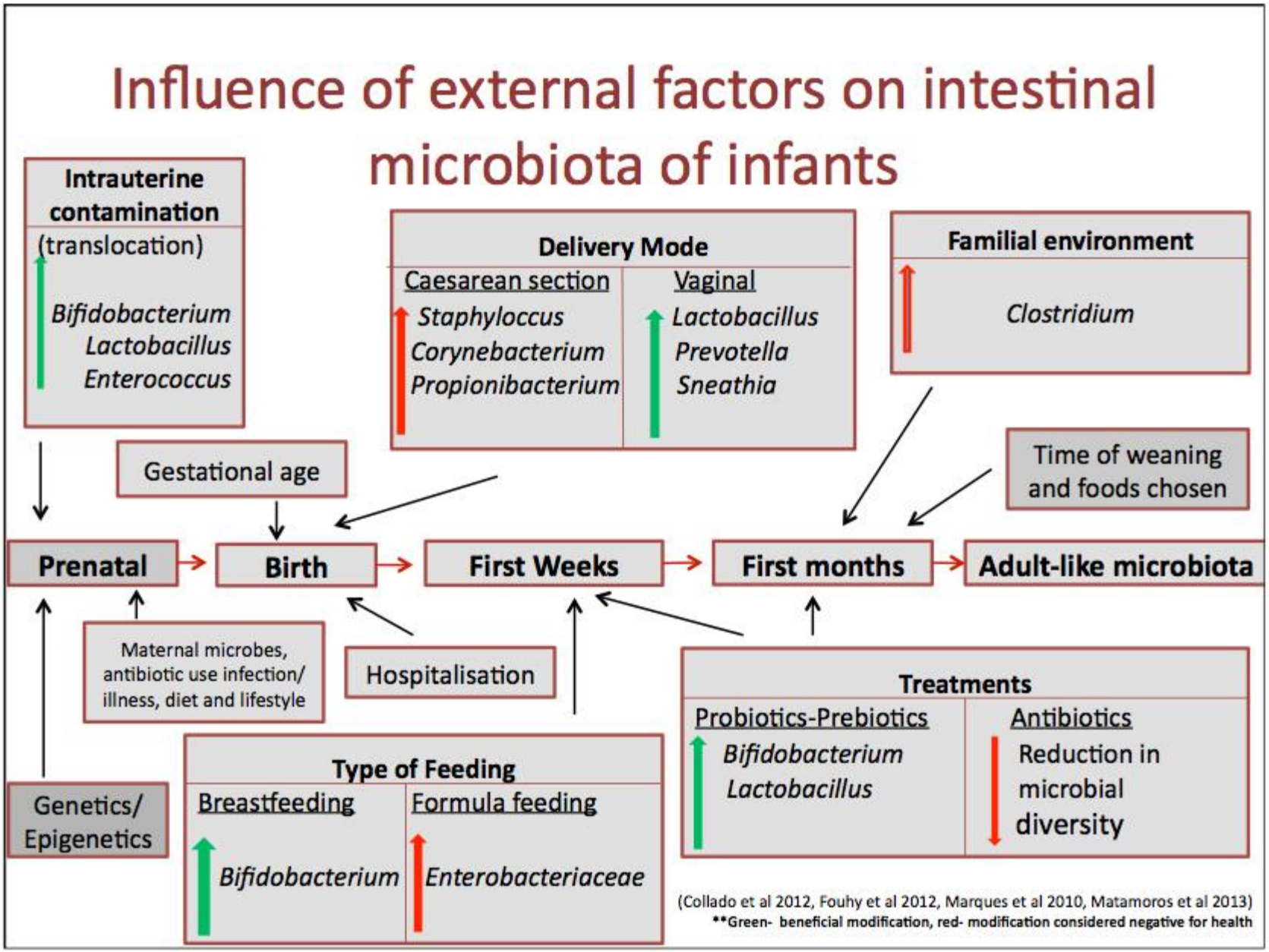
- Differs from term infants due to immaturity, antibiotics, and the hospital environment
- Preterm infants have an increased colonization by potentially pathogenic microorganisms, show reduced diversity, have reduced levels of anaerobes
- This imbalance of microbiota was correlated with NEC and late-onset sepsis

Intestinal Microbiota in the Very Premature Infant

- "Because of the immature intestines, fluctuations in perfusion and oxygenation, and lack of microbial diversity; there is great risk for pathogenic bacteria to overgrow, cause inflammation and/or leak into the bloodstream at sites of mucosal injury."

- Dollings & Brown, An Integrated review of Intestinal Microbiota in the Very Premature Infant. Neonatal Network, 2016.

Influence of external factors on intestinal microbiota of infants



(Collado et al 2012, Fouhy et al 2012, Marques et al 2010, Matamoros et al 2013)

**Green- beneficial modification, red- modification considered negative for health

Antibiotic Use

- Alters the oral and intestinal microbiota composition
- Adult studies show that antibiotics reduce microbial diversity within days and may upset the GI tract for several years
- C-section Moms are routinely given antibiotics
- Could the antibiotics be a factor in the different gut microbiome of the C-section delivered infant and influence higher asthma, allergy, type 1 diabetes and celiac disease rates?

Antibiotic Use in Infants

- Effect on the native gut microbiota is pronounced in infants at 1 year of age
- Overall reduction in community diversity
- Fecal samples from NEC patients had microbial analysis distinct from the control group
- An increased incidence of NEC may be related to the use of broad-spectrum antibiotics in VLBW infants, as well as C-sections.

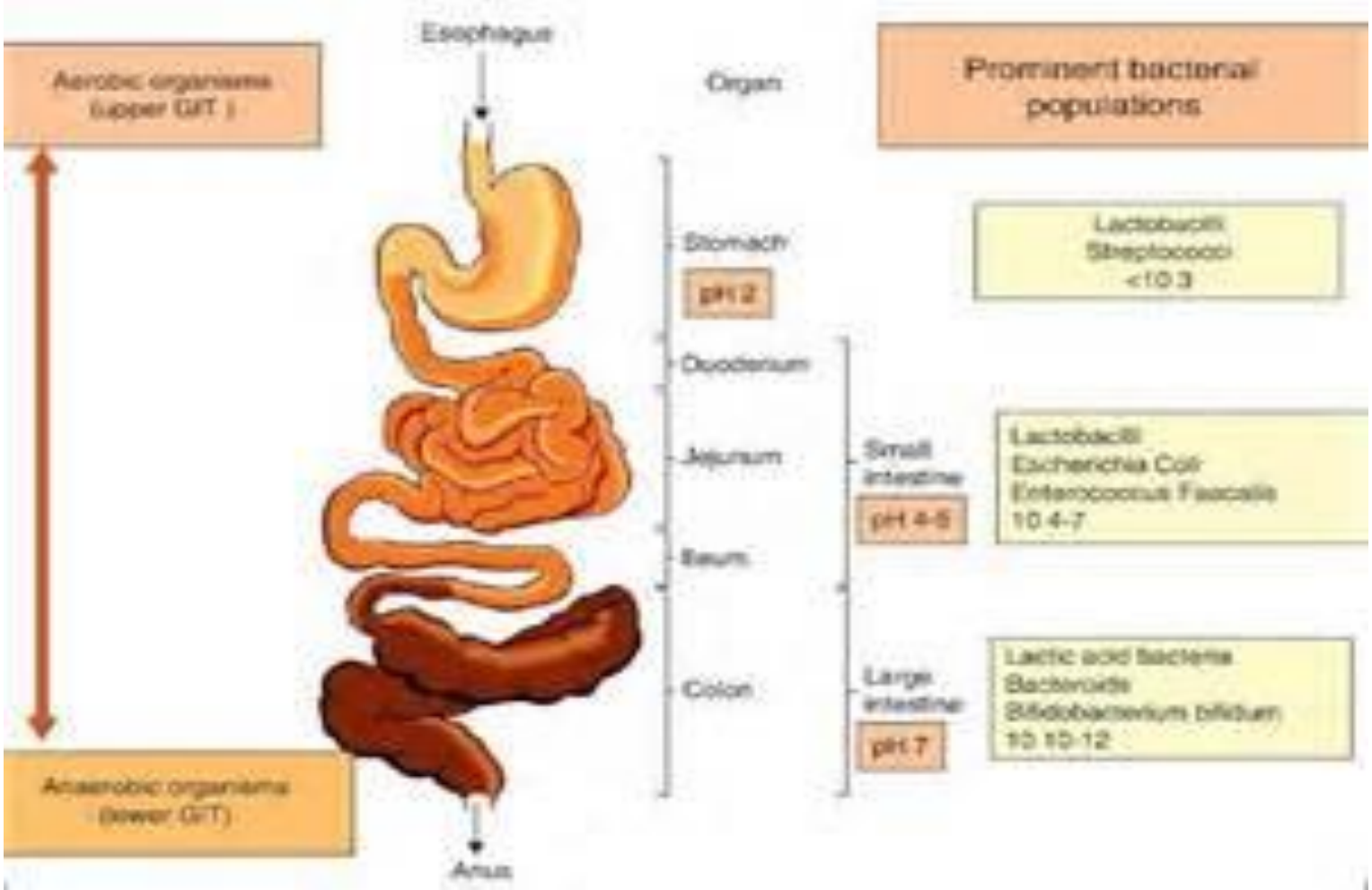
Factors that Promote Healthy Microbiota in the Neonate

- Vaginal delivery
- Term birth
- Skin-to-Skin after birth
- Breastfeeding
- Avoidance of antibiotics
- Term delivery
- Exposure to a variety of microorganisms
- Swab Seeding

Breastfeeding

- Microbes supported by breastfeeding may provide protection against disorders such as neonatal diarrhea, allergies, necrotizing enterocolitis (NEC), obesity and type 2 diabetes

Greater abundance of C.difficile in intestinal microbiota of formula fed infants which has also been associated with eczema

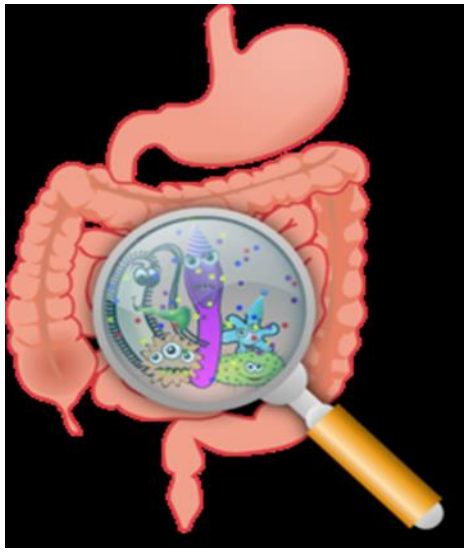


Potential NICU Influences

- Parental skin, feeding type, environmental surfaces, nursing workspaces, and infant caregiving equipment (e.g., ventilators, incubators), healthcare provider skin and antibiotic use were associated with changes in the infant's microbiome
- In one study, intubation and feeding tubes had the highest amount of colonizing organisms detected in the gut

NICU Feeding Practices

- Research should look at the impact of indwelling feeding tubes, bolus vs. continuous feedings, the use of Human milk fortifiers and glycerin suppositories



Skin to Skin Transfer

- No studies to date on Skin to Skin Holding and Microbiome transfer
- Caregivers' skin was responsible for transfer of Staph aureus to the NICU infant
- What needs to be studied is how the NICU environment affects the development of the infant's microbiome over time

- Hartz, et al. Potential NICU Environmental Influences on the Neonate's Microbiome. Advances in Neonatal Care, 2016.

Skin-to-Skin in the OR after Cesarean

- Enhanced Breastfeeding
- Less Cold stress
- Decreased Crying
- Longer periods of alertness

Have a Dog in the Household!

Vaginal Microbial Transfer

- Maria Gloria Dominguez-Bello, a microbiologist at New York University School of Medicine who is at the forefront of research about seeding.
- She recently studied 21 babies in Puerto Rico and found that swab seeding positively affected the microbiome in newborns

Microbiome “Seeding”

A Growing Practice of swabbing a newborn with healthy bacteria from the mom’s vagina

"WE ARE IN THE MIDST OF THE LARGEST EXPERIMENT IN HUMAN HISTORY."

PROF. SUE CARTER
BIOLOGIST & BEHAVIOURAL NEUROBIOLOGIST

MICROBIRTH

REVEALING THE MICROSCOPIC EVENTS DURING CHILDBIRTH THAT COULD HOLD THE KEY TO THE FUTURE OF HUMANITY

WINNER
LIFE SCIENCES FILM FESTIVAL
PRAGUE
2014


SAVE
THE
BACTERIA
IT'S THE ONLY
CULTURE SOME
PEOPLE HAVE

THE END…

“Microbirth”

- Questions...."How will you help me seed and feed my baby's microbiome?"
- Image supplied by Toni Harman
- Our 60 minute Microbirth documentary launches this Saturday 20 September 2014 with hundreds of premiere screenings happening all around the world.
  From the launch date, the film will also be available to stream online as a video-on-demand on the website http://microbirth.com

“The single most important thing we can do for a healthy baby across a life-course is to ensure that microbial seeding occurs completely at birth through vaginal delivery when possible, that skin-to-skin contact occurs and that the microbes are supported through breastfeeding of significant duration.

Because that is what is going to influence the health across a life-span versus one filled with disease for that child.“

Dr. Sandy Dietert,

What About Health Care Workers?

They said they thought people were chasing them; one wound up impaled on a fence.

The common element to these and other bizarre incidents in Florida in the last few months is flakka, an increasingly popular synthetic designer drug. Also known as gravel and readily available for $5 or less a vial, it's a growing

to be abused. It is usually made overseas in countries such as China and Pakistan.

Flakka, a derivative of the Spanish word for a thin, pretty woman, is usually sold in a crystal form and is often smoked using electronic cigarettes, which are popular with young people and give off no odor. It can also be snorted, injected or swallowed.

"I've had one addict describe it as $5 insanity," said Don Maines, a drug treatment counselor with the Broward Sheriff's Office in Fort Lauderdale. "They still want to try it because it's so cheap. It gives them heightened awareness. They feel stronger and more sensitive to touch. But then the paranoia sets in."

Judging from the evidence being seized by police around Florida, flakka use is up sharply. Submissions for testing to the Florida Department of Law Enforcement's crime labs have grown from 38 in 2013 to 228 in 2014. At the Broward Sheriff's Office laboratory, flakka submissions grew from fewer than 200 in 2014 to 275 in the first three months of this year, according

to spokeswoman Keyla Concepcion.

"It's definitely something are watching. It's an emergi drug," said Chad Brown, an Florida Department of Law Enforcement supervisory special agent.

According to the Nationa Institute on Drug Abuse, Fl da appears to be the nation hot spot for reports of flak

HEALTH

FDA seeks data on hospital hand cleaners' safety

ASSOCIATED PRESS

WASHINGTON — To fight infections, hospital workers can hit the hand sanitizer a hundred times or more a day. Now, the government wants more study of whether that is safe and how well it actually fights the spread of germs.

The Food and Drug Administration is asking manufacturers to submit additional data about medical hand washes and sanitizers, including the long-term health effects of their daily use on the skin.

Under a proposed rule published Thursday, companies must submit new studies looking at key safety issues, including possible hormonal effects and contributions to antibiotic-resistant bacteria. Products that are not shown to be safe and effective by 2018 would have to be reformulated or removed from the market.

According to an agency estimate, it could cost companies between $64 million and $90 million to conduct the requested studies and comply with new requirements.

For now, the FDA stressed that health care workers should continue using hand washes, sanitizers and surgical scrubs, which are standard tools for preventing health care infections.

"We're not asking for any of these products to come off the market at this time, we're just asking for additional data," said Theresa Michele, a director in the agency's drug center. "And we're likewise not suggesting that people stop using these products."

The antiseptic ingredients at issue, including alcohol and iodine, have been used by doctors and nurses for decades. But FDA scientists say their routine use has increased over the past 20 years as hospitals ramped up efforts to fight infections. Widely adopted guidelines recommend doctors and nurses sanitize their hands before and after visiting each patient's room.

Regulators are also concerned about emerging science suggesting antiseptics are absorbed into the body at higher levels than previously thought,

showing up in the blood a urine of users.

The FDA wants compa provide data from both h and animal studies on ab tion rates, blood levels, t ogy and possible links t and hormonal problem ulators say they will us information to determi thresholds for users.

The FDA also wants mation about possible between use of antisep the growth of what are called superbug bacte are resistant to antibio

Conclusions

- Goal is to protect neonatal skin and promote future skin health
- Normal skin flora are helpful in protecting skin from infection
- Care practices should promote presence of commensal bacteria
- Bathing with water alone may not be better than using gentle baby wash
- Skin disinfection vs. maintenance & promotion of commensal bacteria is a complicated issue

First Bath

- AWHONN Guideline:
  - Vital signs, temperature stable 2-4 hours
  - Antiseptic cleaners not currently required by American Academy of Pediatrics, Center for Disease Control
  - Universal precautions until bathed
  - Not necessary to remove vernix
- World Health Organization (WHO): wait at least 6 hours
- Although studies indicate that newborns bathed as soon as 1 hour after delivery will maintain their temperature (if they have a normal temperature to begin with)… should they be?

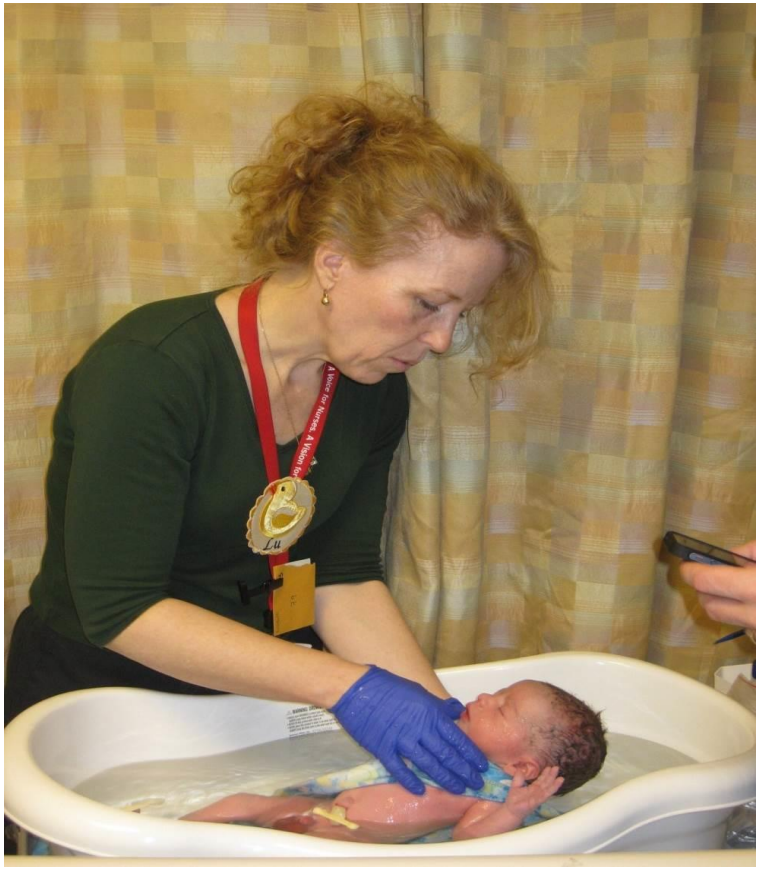
Bathing and Skin Care

- Moisturizers and Barrier creams affect local microenvironment potentially shifting microbial composition
- pH changes effect bacterial

ABSTRACT

The skin microbiome colonizes humans at birth and the community structure and diversity continue to change throughout the course of life, as our previous work has demonstrated. These community changes correlate with the various microenvironments on the skin as well as changes in skin structural and functional properties over time. While time and body site location clearly affect skin microbiome evolution, little is known about the impacts of typical hygiene practices at birth and throughout life on the skin microbiome. To examine the effects of hygiene practices on the skin microbiome at birth, we assessed the skin microbiomes of 50 vaginal-delivered and 50 Cesarean section pre-term and term neonates at birth and examined the impact of the first bath, given hours within birth, on the primary skin microbiome in both cohorts. In addition to the first bath itself, we also assessed the effects of bathing in water alone or water with a mild baby cleanser. On the skin microbiome at birth. To examine the effect of daily hygiene practices on adults, we explored the effects of daily use of a liquid castile soap, a mild baby cleanser, and a mild facial cleanser over 4 weeks in adult women.

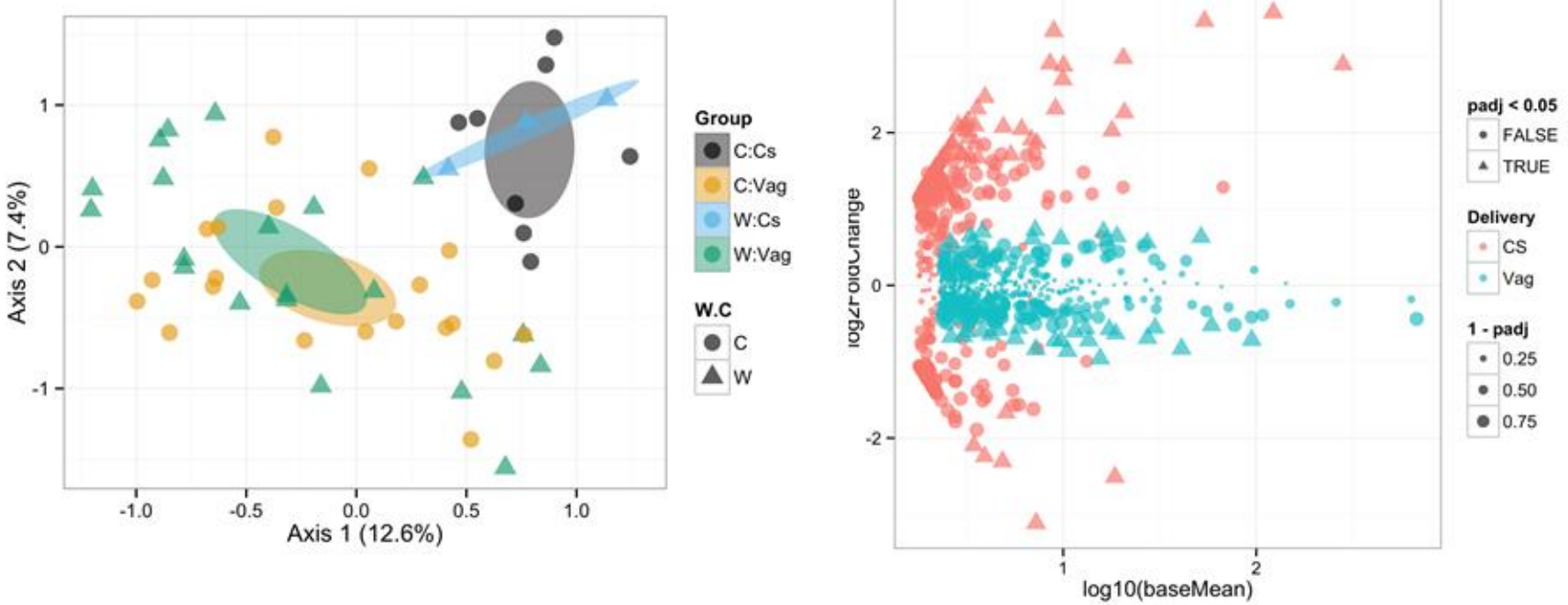
Our “First Bath” Study



- 100 babies randomized to first bath with water alone or water with liquid baby wash
- 50 vaginal birth, 50 C/S
- All babies immersed and swaddled in the bath
- Pre and Post-Bath:
  - pH
  - TEWL
  - stratum corneum hydration
  - Water pH, hardness
  - Skin microbiome (baby, mom)

Figure 2. Delivery Mode Shaped Effects of the First Bath on the Skin Microbiome at Birth .

- Addition of Head-To-Toe® to Infants' First Bath Water Did Not Influence Effects of the Bath on the Microbiome. $p > 0.05$



Vernix Caseosa

- Fetal protective skin barrier—unique to humans
  - Primarily water (80%), lipids, protein
  - Production begins end of 2nd trimester, most accumulated 36-38 wks
  - Vernix detaches from skin as levels of pulmonary surfactant rise
- Assists in temperature regulation, cleansing, formation of acid mantle
- Allow to wear off naturally

Antibiotic Use

- Alters the oral and intestinal microbiota composition
- Adult studies show that antibiotics reduce microbial diversity within days and may upset the GI tract for several years
- C-section Moms are routinely given antibiotics
- Could the antibiotics be a factor in the different gut microbiome of the C-section delivered infant and influence higher asthma, allergy, type 1 diabetes and celiac disease rates?

Antibiotic Use in Infants

- Effect on the native gut microbiota is pronounced in infants at 1 year of age
- Overall reduction in community diversity
- Increase in “less desirable” and

  antibiotic resistant strains of bacteria and C. difficile associated diarrhea
- Fecal samples from NEC patients had microbial analysis distinct from the control group
- An increased incidence of NEC may be related to the use of broad-spectrum antibiotics in VLBW infants.

Should We Reconsider Antimicrobial Bathing?

- Concerns about community-acquired MRSA
- Newborns seen in emergency departments with cellulitis, skin infections due to MRSA
- Hospital-acquired infection

Misadventure in Neonatal Skin Care: Hexachlorophene

- Hexachlorophene was used to control outbreaks of *s. aureus* infection in nurseries
- Reports in 1970s of spongiform myelinopathy in LBW infants
- Anderson (1981):
  - Autopsied 27/97 infants (<1750 grams) who expired over 2 year period
  - HCP bath daily, and to diaper area with changes
  - 20 had brain myelinopathy on autopsy to varying degrees
  - Worst cases seen in infants who survived longer
  - Also saw brain abscesses from candida in one infant, E. coli meningitis in another

Increased Risk of Toxicity from Topical Agents in Newborns

- Larger surface area (compared to body weight) exposed to topical agent
- Stratum corneum maturity and integrity are factors, especially in premature infants
- pH of skin surface: more alkaline pH increases permeability
- Occlusion (ie, wearing a diaper) compromises stratum corneum, skin barrier function
- Immature renal and hepatic function to excrete absorbed agents

Chlorhexidine Baths for Newborns

- **Da Cunha (2008):** RCT of 94 full term newborns

  cleanser vs. 0.25% CHG

  staph aureus colonization reduced at 24 hours (36.7% vs 13.6% with CHG)

- **Sankar (2009):** RCT of 60 premature infants 28-36 weeks

  0.25% CHG, saline, no cleansing

  CHG reduced colonization by half in the axilla at 24 hours but not at 72 hours

  no difference in the groin at 24 or 72 hours; skin scores not changed

Blood Concentration of CHG in Hospitalized Children Undergoing Daily CHG Bathing

Lee et al (2011) Inf control and Hosp Epidemiol 32:395-397

- 12 subjects, 3 months – 17 years
- Mean # of daily baths 9 (range 1-30)
- 8 subjects had samples after at least 7 days CHG exposure
- Low concentrations CHG
- No evidence CHG accumulation

Chlorhexidine Gluconate Bathing?

- Daily baths in PICU reduced BSIs
- Safety in neonates?
- Influence on normal colonization, barrier function?

AHRQ Guideline: Daily Bathing of children in Critical Care Settings with CHG (2013)

- Best evidence statement from Cinncinati Children's
- "It is strongly recommended that patients (with intact skin) receiving care in an inpatient critical care setting receive a daily bath using 2% CHG to reduce the risk of bloodstream infection"
- Exclusions:
  - < 2 months
  - Indwelling epidural or lumbar drain
  - Known sensitivity to CHG

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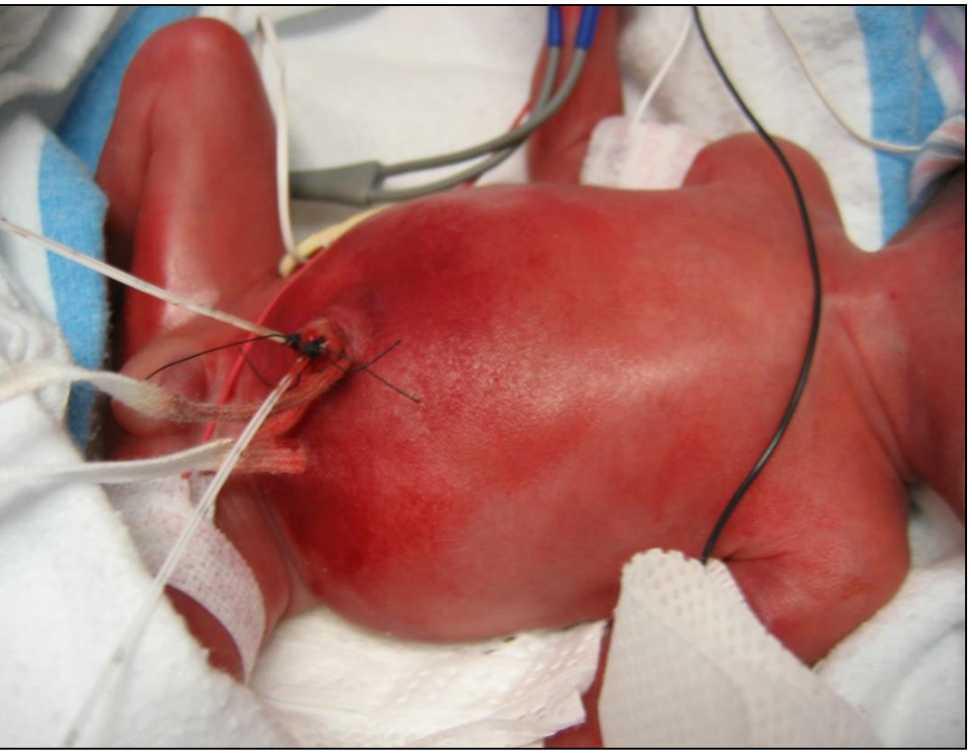
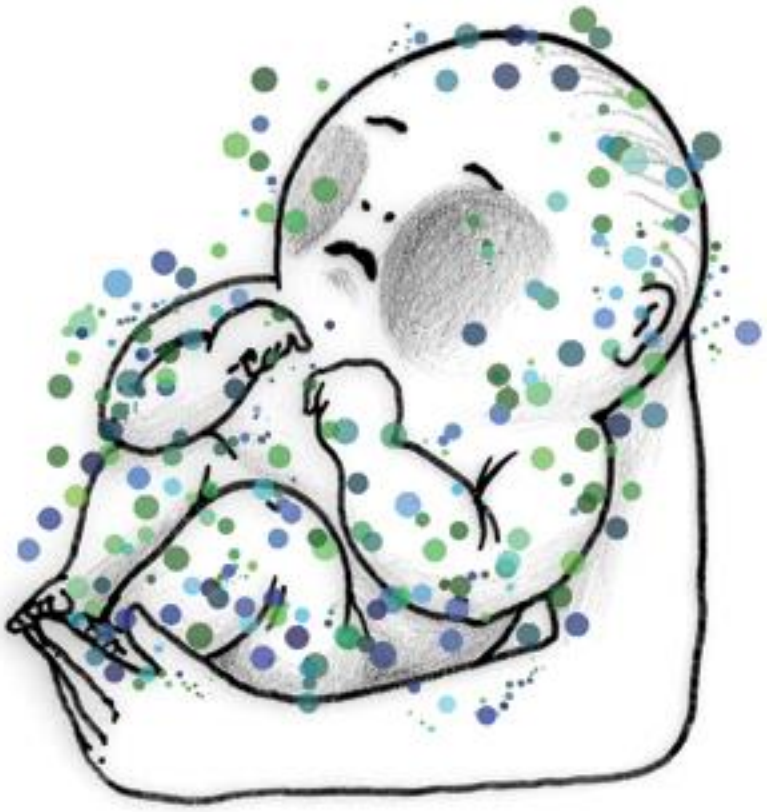
FDA Labeling (2013) for CHG/isopropyl alcohol agents

"Use with care in premature infants less than 2 months of age. These products may cause irritation or chemical burns."

Chemical Burns:
2% CHG with 70% Isopropyl Alcohol



Abnormal Gut Bacteria present in some 1-month olds might Promote Asthma



- Nature Medicine 9/12/16

Infants with Neonatal microbiota with lower levels of Bifidobacteria, Lactobacillus, Faecalibacterium, & Akkerkmansia with higher levels of fungi including Candida were allergy prone at age 2 and several diagnosed with asthma at age 4

3 years to adulthood

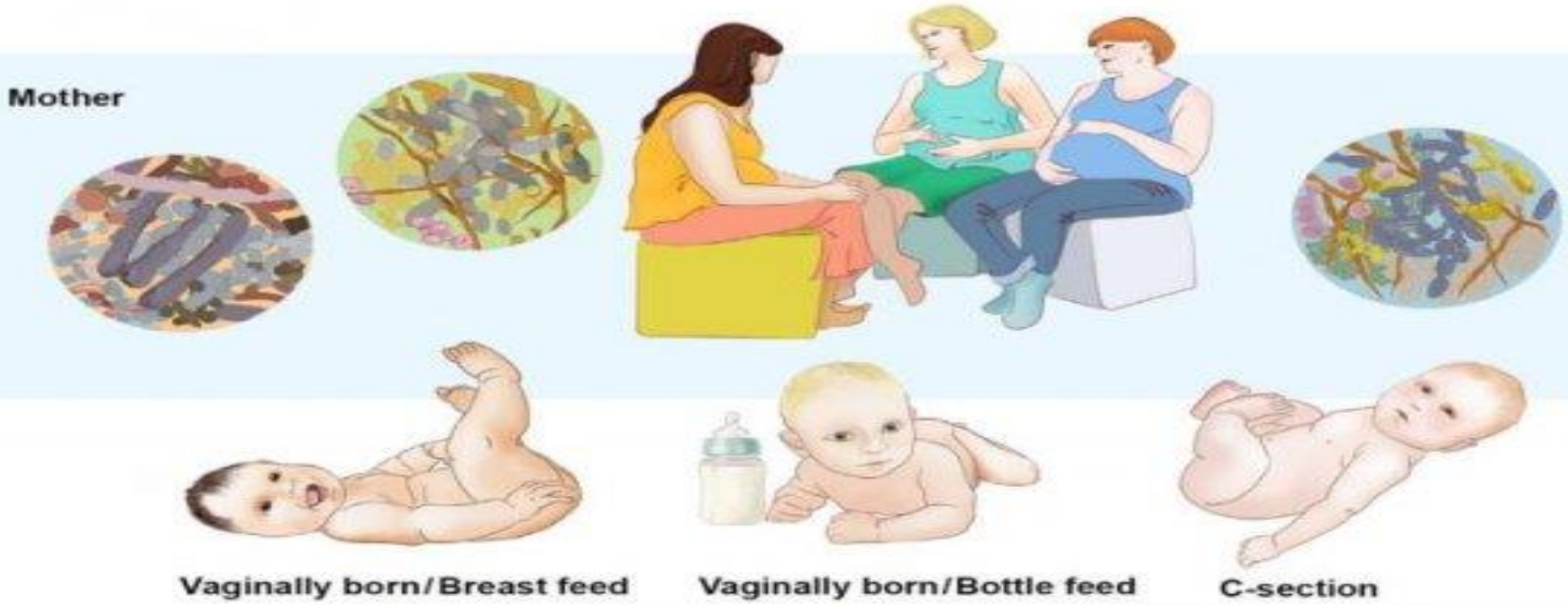
3 years - adulthood

By age three, a child's microbiome looks a lot like an adult's, and it becomes much more stable. It still continues to change in response to events like illness, disease, antibiotic treatment, fever, stress, injury, and changes in diet. But the population still tends to shift back to a "baseline" state.

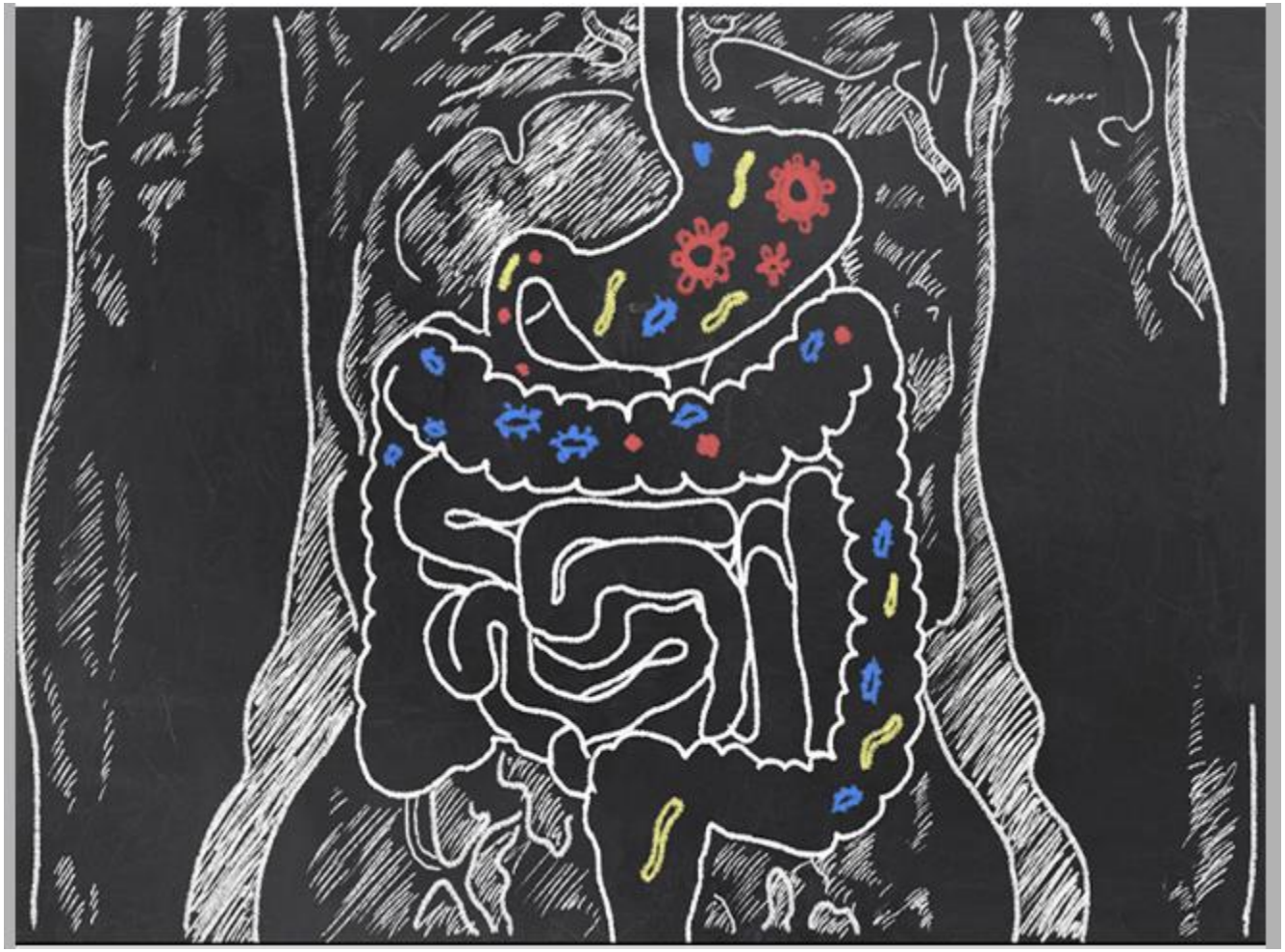
Major life events—like puberty, pregnancy, and menopause—can cause larger shifts. For example, puberty affects skin microbes by causing changes in skin oils. And pregnancy brings on changes in the vaginal microbiome: species start to grow that will colonize and benefit the baby as it's born.

Visit the Microbiome Simulator to learn more about how life events influence our microbial populations.

How skin microbiota affect human skin cells:
Proteases may affect corneocyte desquamation.
Lipases break down skin surface lipids with potentially irritant by-products.
May provide antigens to the skin-residing immune cells.
Help with defenses against “common enemies.”
Quorum-sensing molecules may affect skin cells? (unknown)
How human skin cells affect skin microbiota:
Provide nutrients.
Control growth through innate immunity, i.e., antimicrobial peptides and lipids, and by controlling the skin surface pH, i.e., the “acid mantle.”
Control virulence by creating a physical barrier to penetration.
Control population composition by creating local microenvironments (moist, dry, sebaceous).
How skin care routines/products may affect skin microbiota:
Massage may facilitate microbiome transmission from parent to baby.
Surfactants in skin cleansers may interact with microbial membranes.
Moisturizers affect local microenvironments, potentially shifting microbial compositions.
Barrier creams may fortify the skin surface against microbial penetration.
Preservative effects? (unknown)
Product pH effects? (unknown)


Mother
Vaginally born/Breast feed
Vaginally born/Bottle feed
C-section
4 days
4 month
12 month

Intestinal Microbiota in the Very Premature Infant



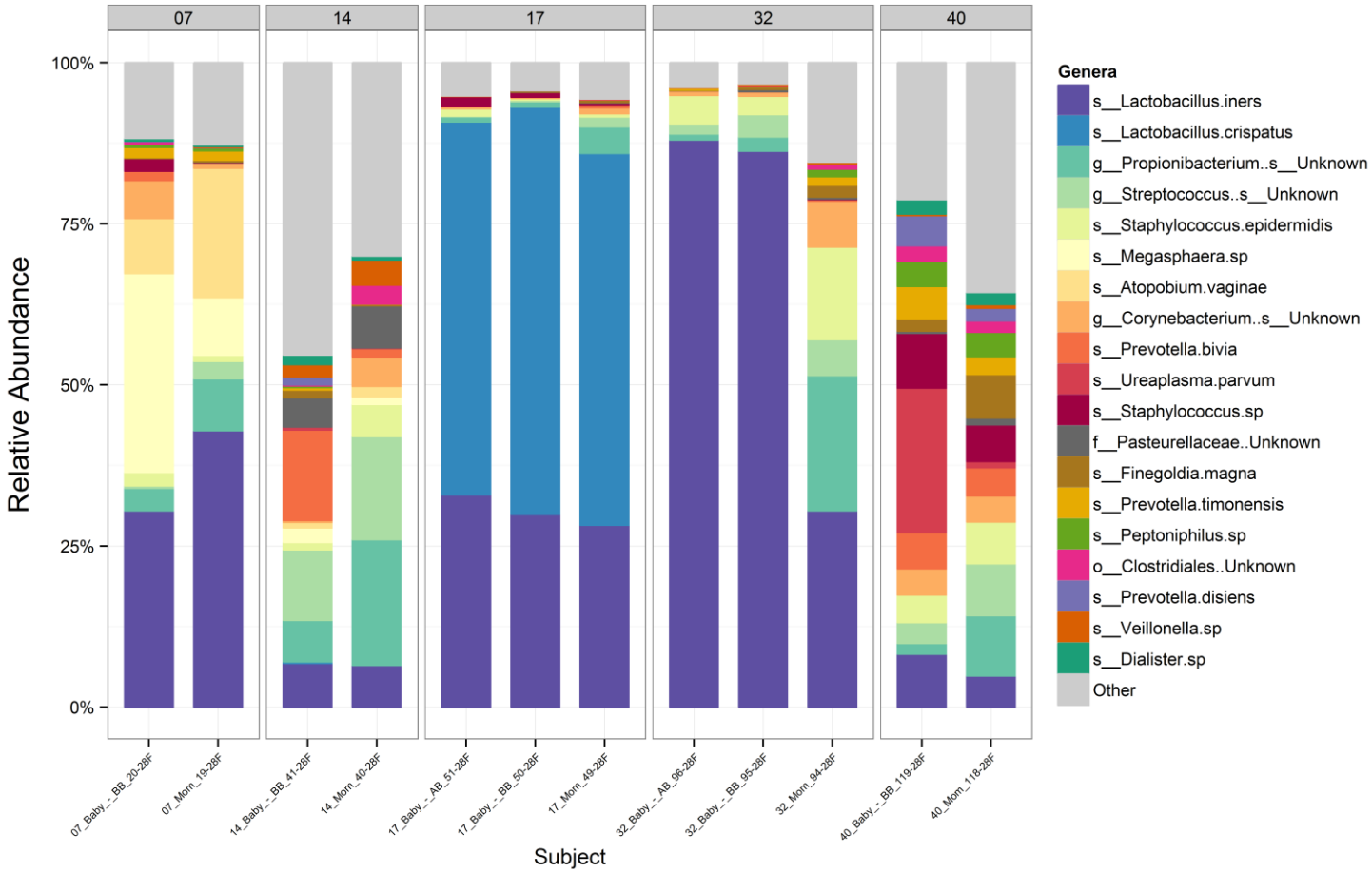
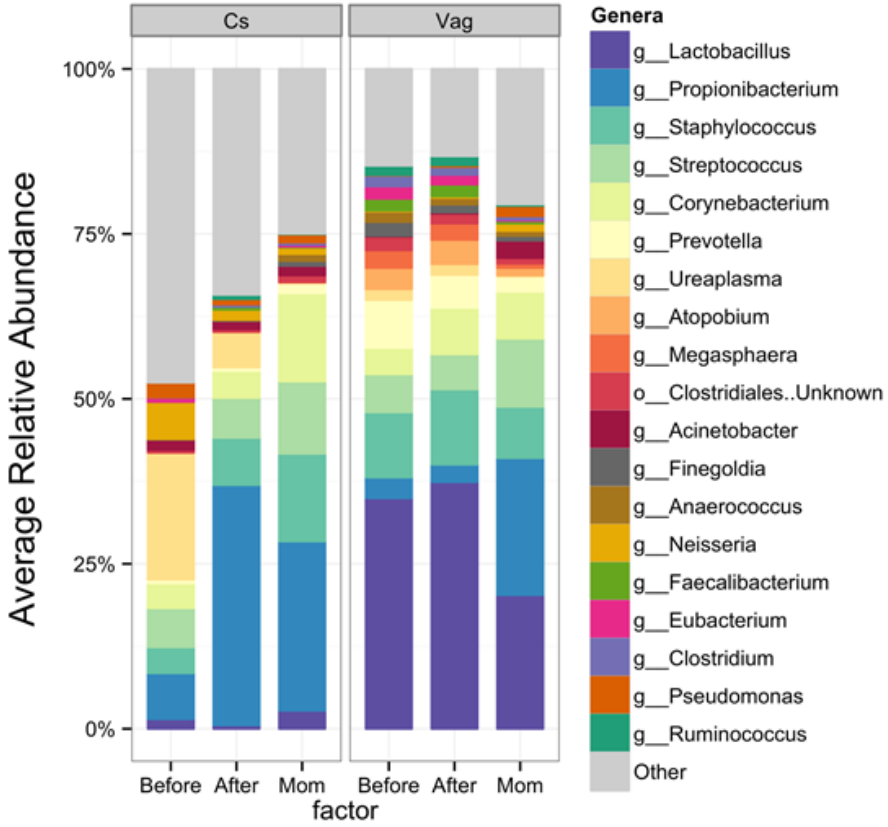
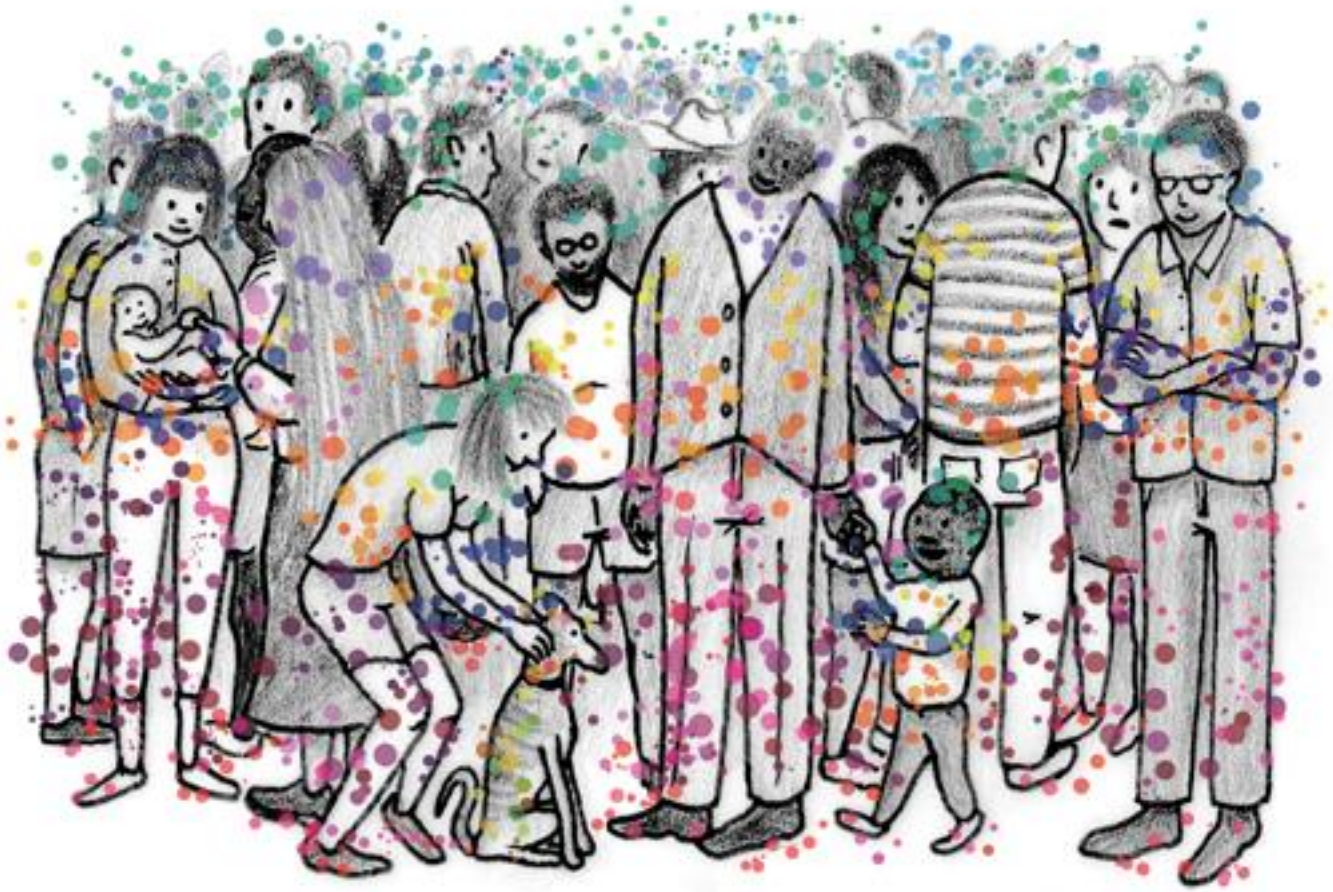
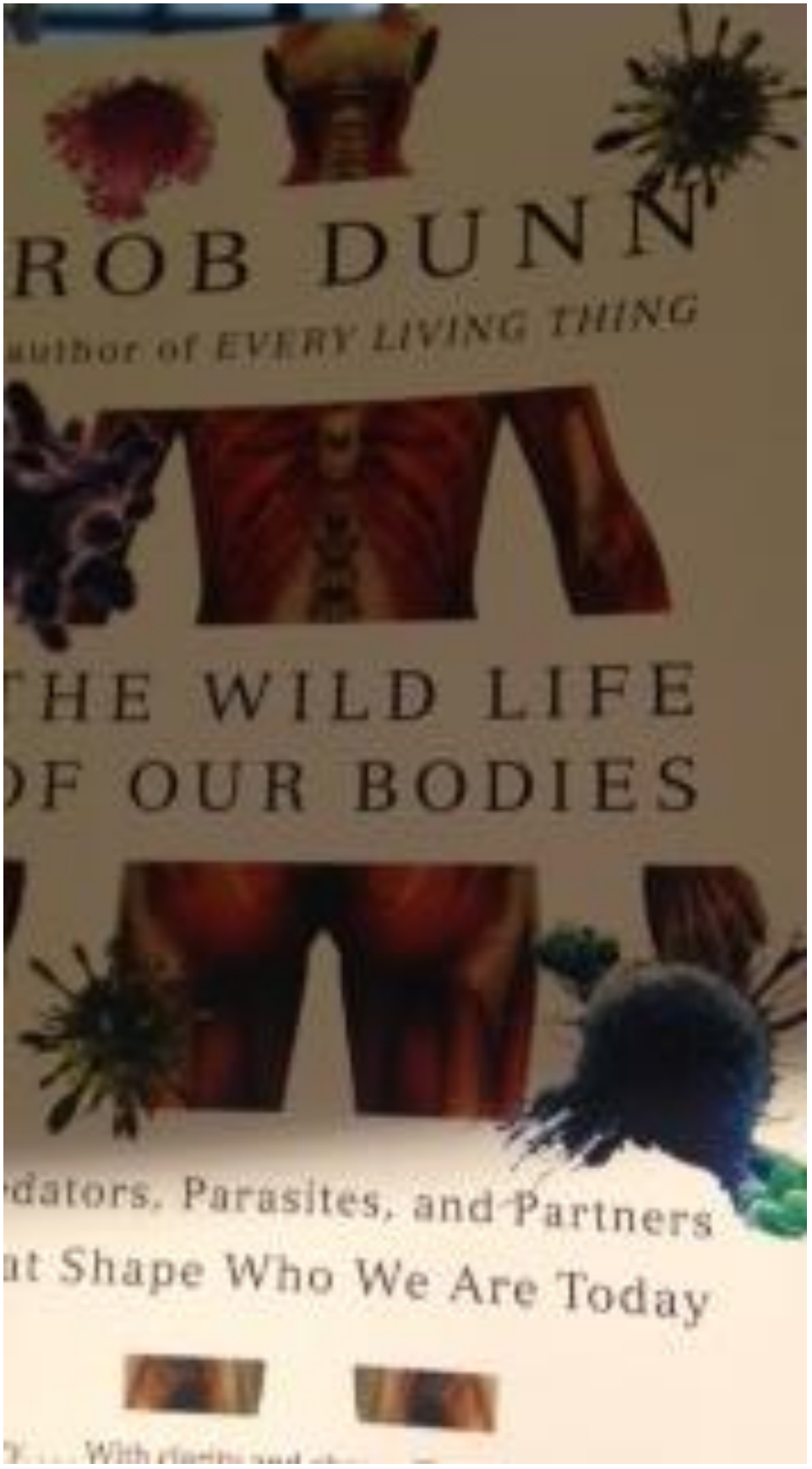
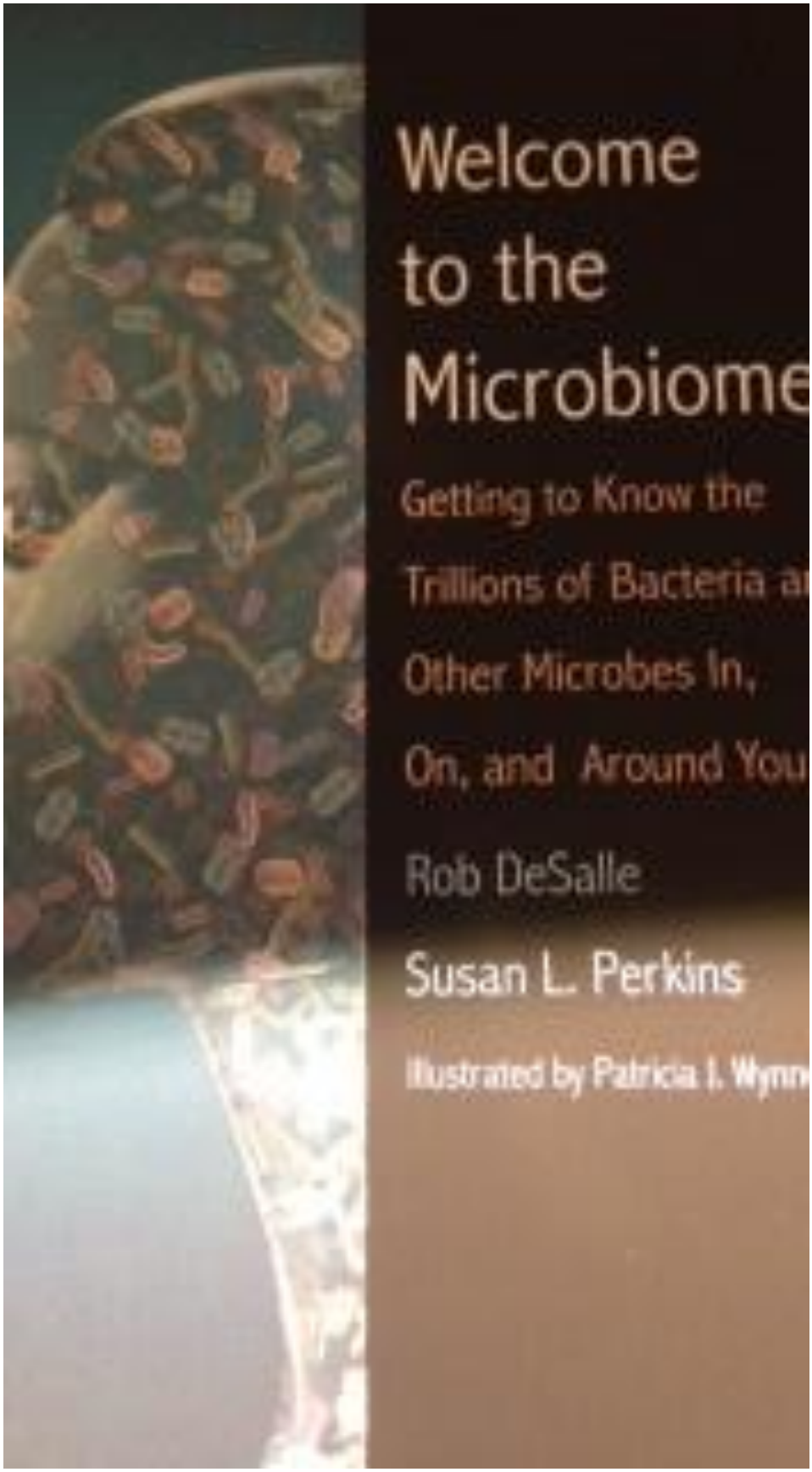

07
14
17
32
40
100%
75%
50%
25%
0%
Relative Abundance
07_Baby_-_BB_20-28F
07_Mom_19-28F
14_Baby_-_BB_41-28F
14_Mom_40-28F
17_Baby_-_AB_51-28F
17_Baby_-_BB_50-28F
17_Mom_49-28F
32_Baby_-_AB_96-28F
32_Baby_-_BB_95-28F
32_Mom_94-28F
40_Baby_-_BB_119-28F
40_Mom_118-28F
Subject
Genera
s__Lactobacillus.iners
s__Lactobacillus.crispatus
g__Propionibacterium..s__Unknown
g__Streptococcus..s__Unknown
s__Staphylococcus.epidermidis
s__Megasphaera.sp
s__Atopobium.vaginae
g__Corynebacterium..s__Unknown
s__Prevotella.bivia
s__Ureaplasma.parvum
s__Staphylococcus.sp
f__Pasteurellaceae..Unknown
s__Finegoldia.magna
s__Prevotella.timonensis
s__Peptoniphilus.sp
o__Clostridiales..Unknown
s__Prevotella.disiens
s__Veillonella.sp
s__Dialister.sp
Other

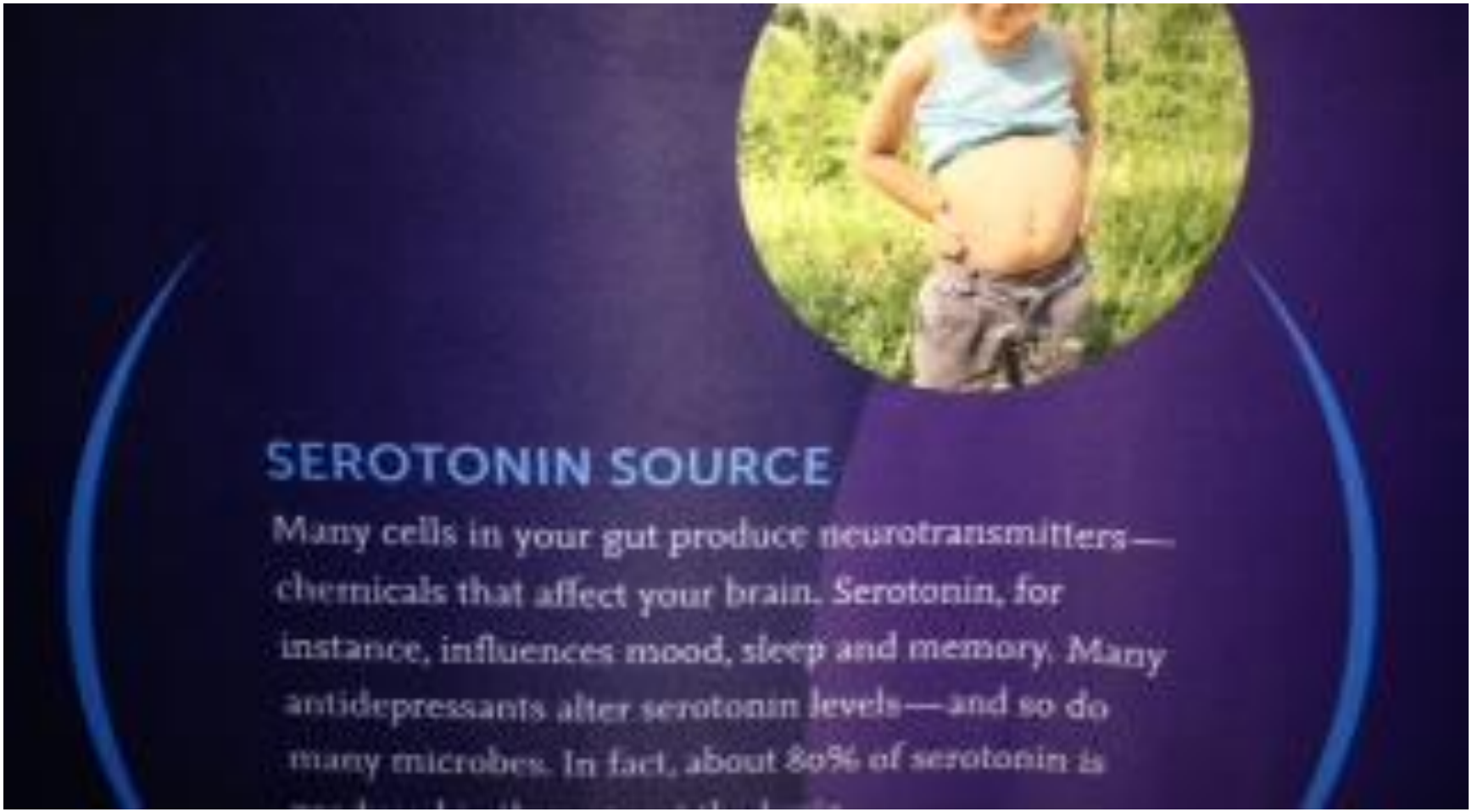
Figure 1. Microbiome Community Structure at Birth Based on Delivery Mode and After the First Bath.






ROB DUNN
author of EVERY LIVING THING
THE WILD LIFE
OF OUR BODIES
dators, Parasites, and Partners
at Shape Who We Are Today


Welcome to the Microbiome
Getting to Know the Trillions of Bacteria a Other Microbes In, On, and Around You
Rob DeSalle
Susan L. Perkins
Illustrated by Patricia J. Wynn


SEROTONIN SOURCE
Many cells in your gut produce neurotransmitters—chemicals that affect your brain. Serotonin, for instance, influences mood, sleep and memory. Many antidepressants alter serotonin levels—and so do many microbes. In fact, about 80% of serotonin is

ZOMBIE MICE

A parasite called *Toxoplasma gondii* lives inside many animals, including some mice. But it can only reproduce inside cats. So how does it get from mice to cats? Incredibly, several studies show that this tiny, single-celled protozoan alters the mouse's brain and controls its behavior.

MY MICROBES MADE ME DO IT

Roughly a third of all humans are infected with *Toxoplasma gondii*, the parasite that turns mice into zombies—and it appears to influence our behavior as well. Some studies show infected men break more rules and dress more sloppily, while infected

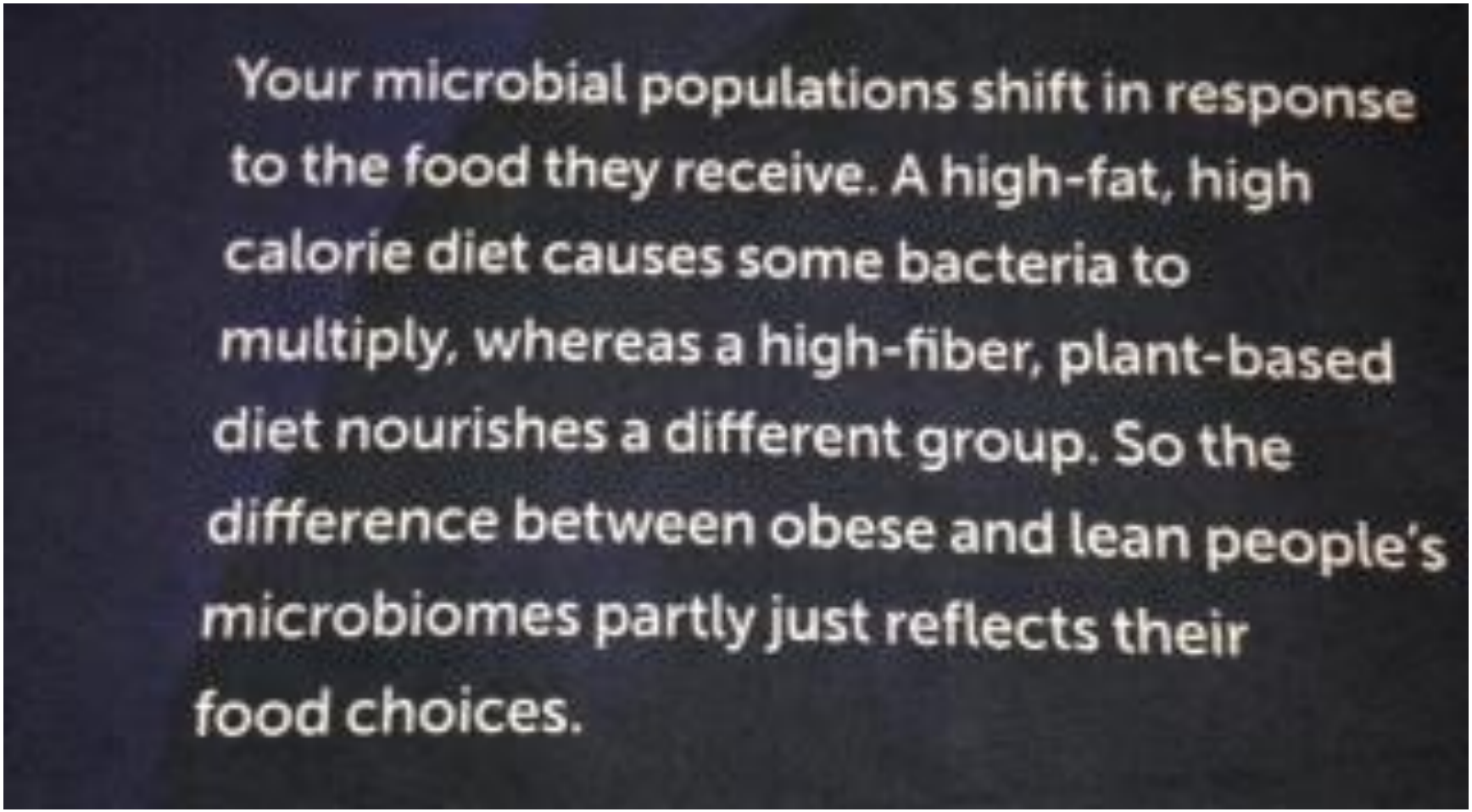
Mind control

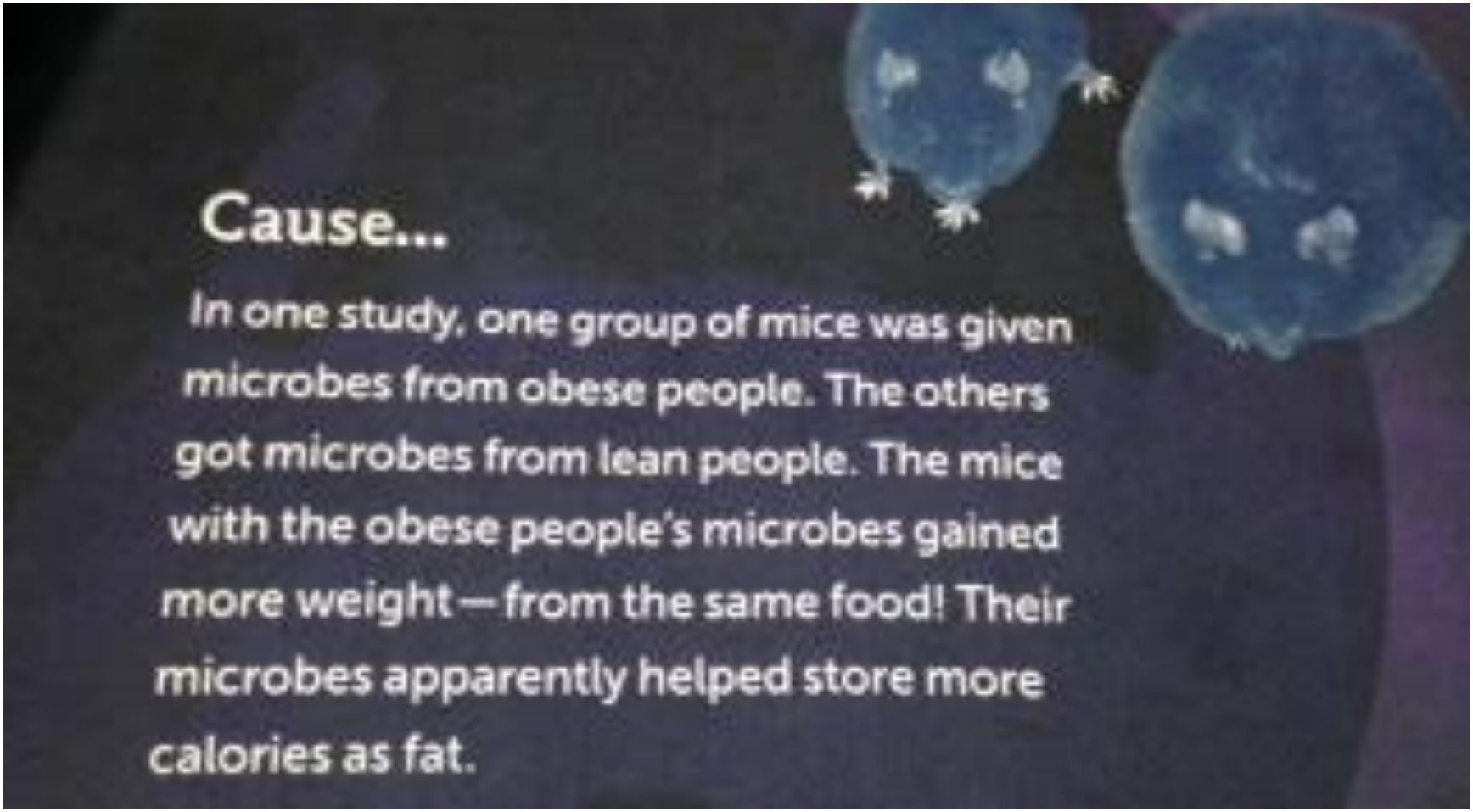
Microbes affect not just your body, but your innermost thoughts and feelings. Early research suggests that appetite, mood, mental illness—even bizarrely specific behaviors like the way we dress—can all be manipulated by microbes.

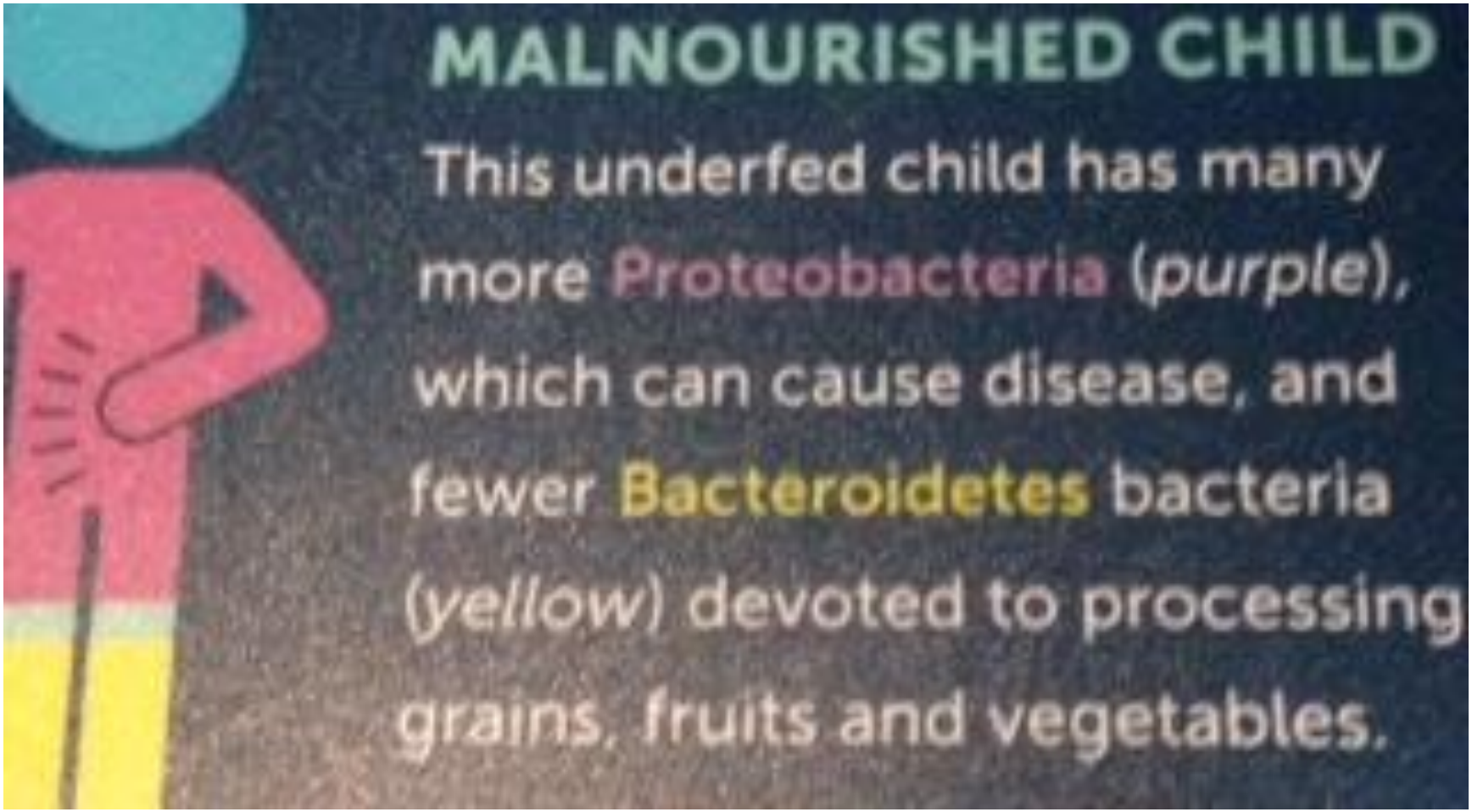

Gut-brain axis
Your second brain


Gut-brain axis
Your second brain
cause of obesity,
...probably both.

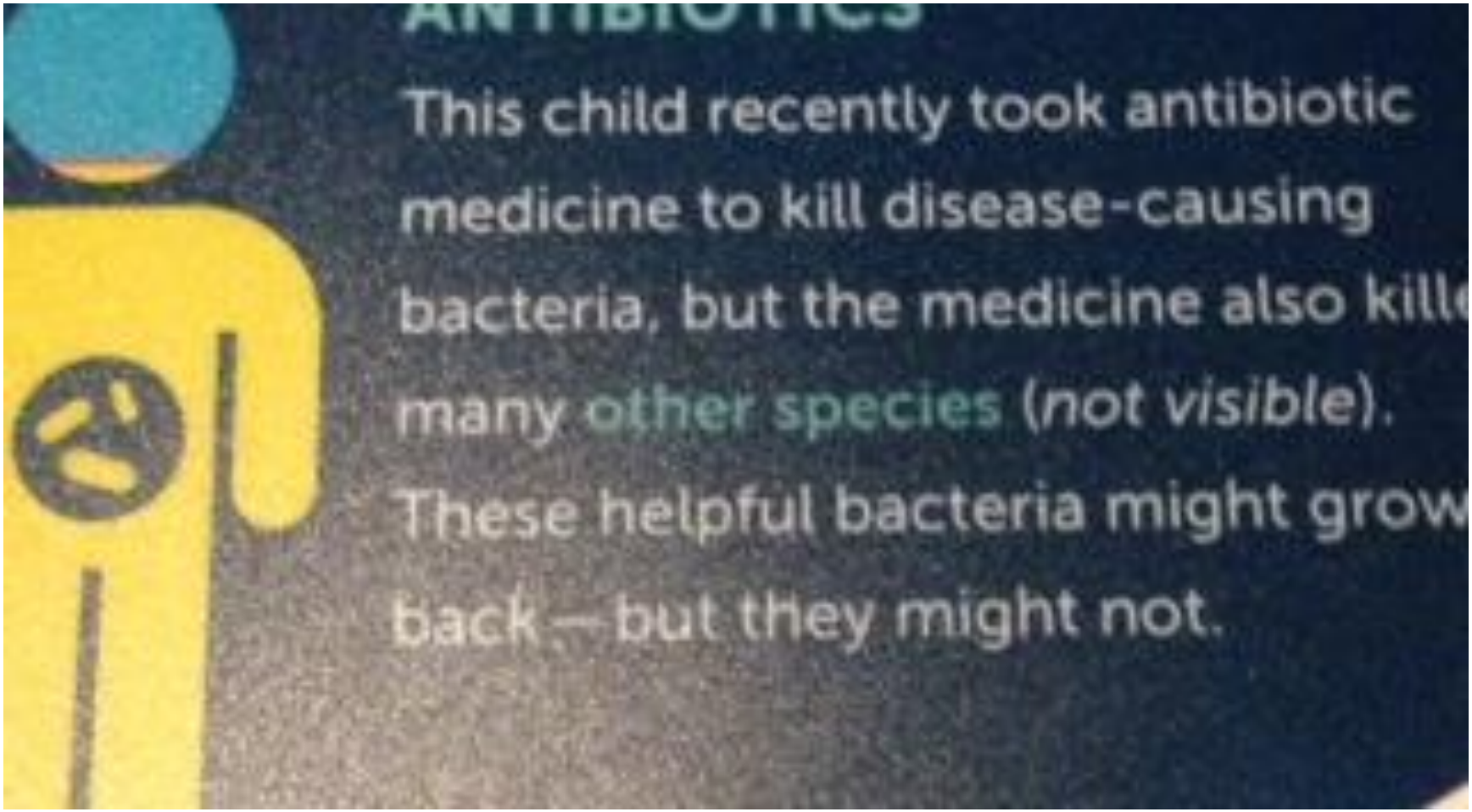
Or effect?

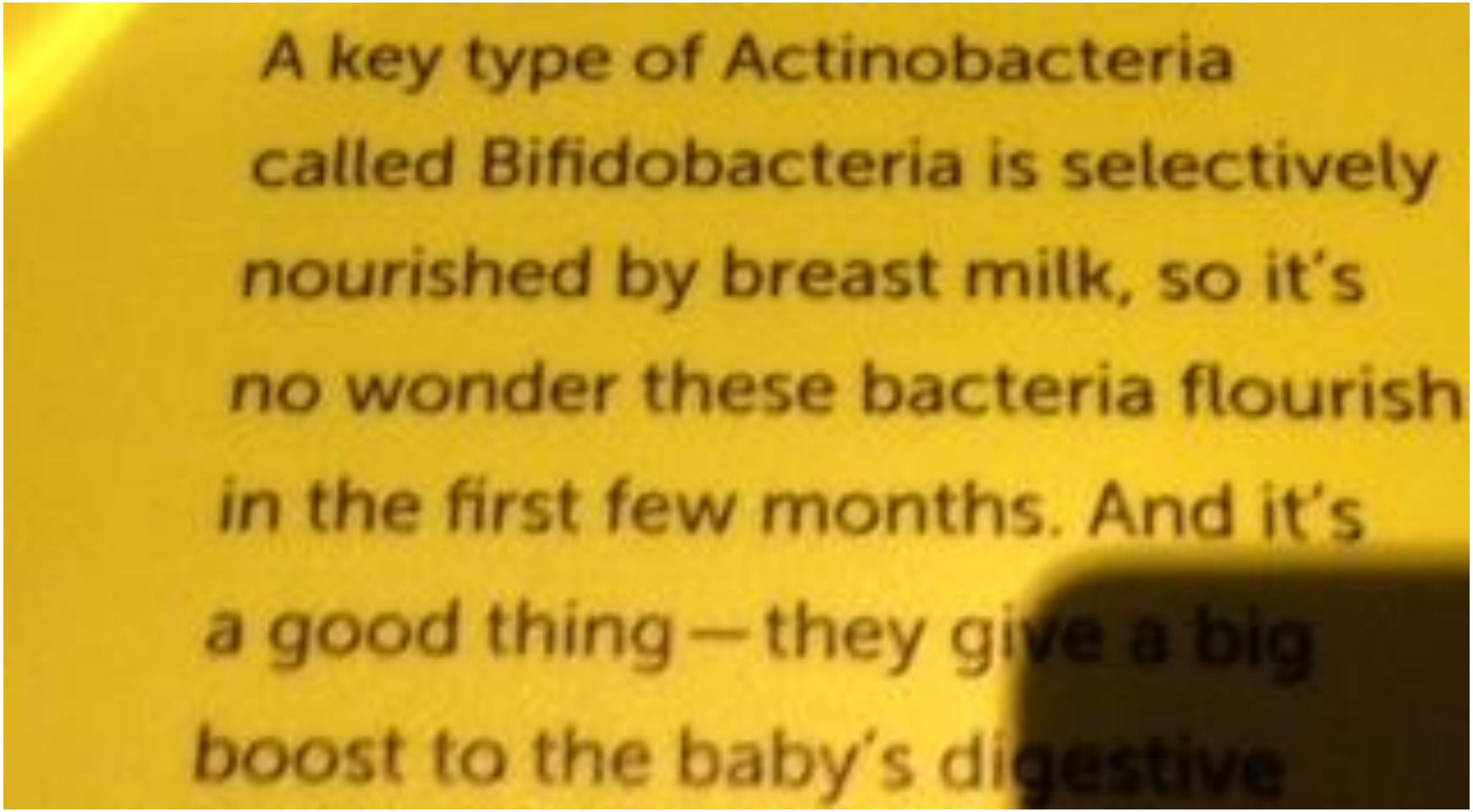

Your microbial populations shift in response to the food they receive. A high-fat, high calorie diet causes some bacteria to multiply, whereas a high-fiber, plant-based diet nourishes a different group. So the difference between obese and lean people's microbiomes partly just reflects their food choices.


Cause...
In one study, one group of mice was given microbes from obese people. The others got microbes from lean people. The mice with the obese people's microbes gained more weight—from the same food! Their microbes apparently helped store more calories as fat.

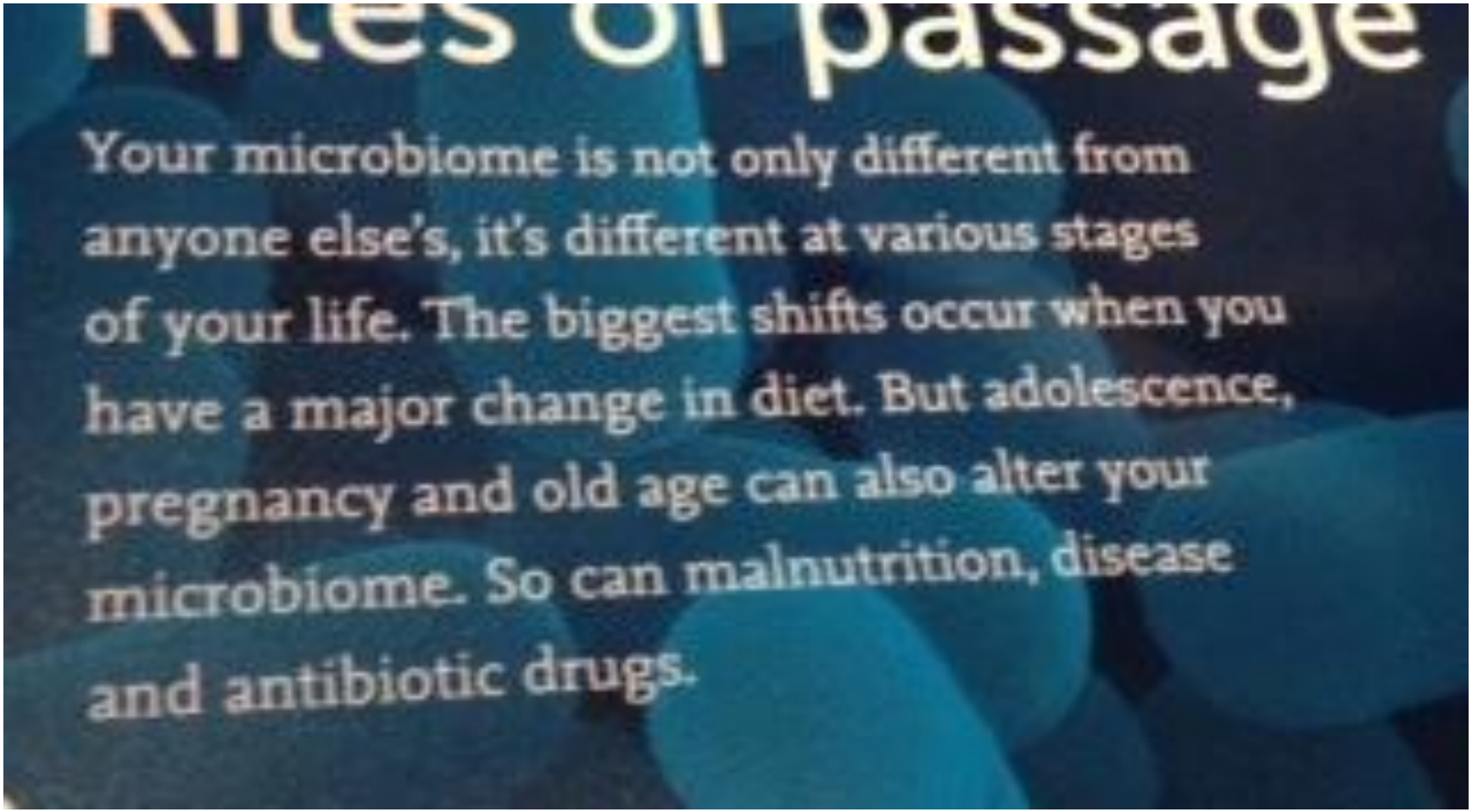

MALNOURISHED CHILD
This underfed child has many more Proteobacteria (purple), which can cause disease, and fewer Bacteroidetes bacteria (yellow) devoted to processing grains, fruits and vegetables.

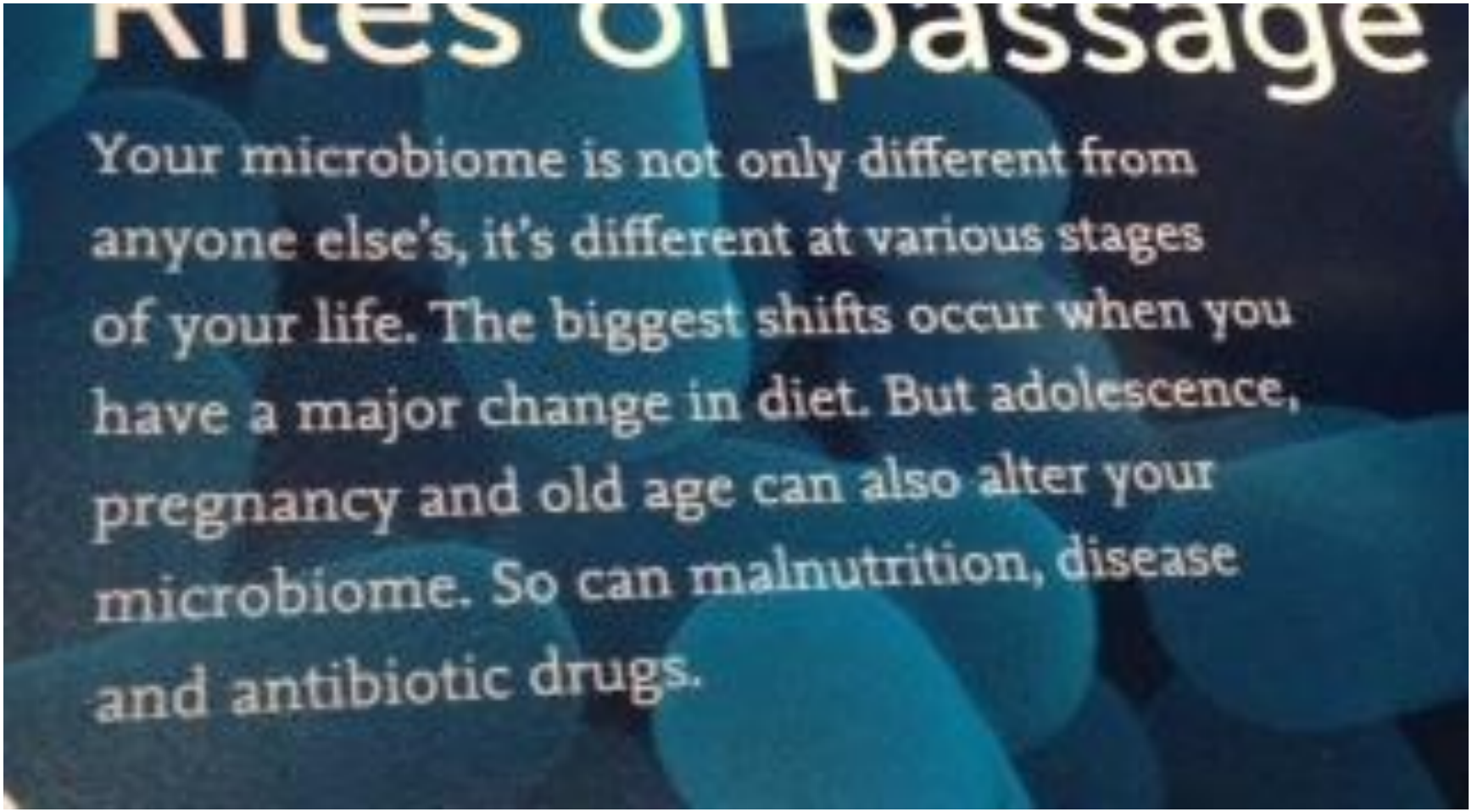

HEALTHY CHILD
This healthy, well-fed child has a microbiome dominated by Bacteroidetes and Firmicutes (*yellow* and *blue*), bacteria that thrive on healthy foods, along with a rich diversity of other species (teal).


ANTIBIOTICS
This child recently took antibiotic medicine to kill disease-causing bacteria, but the medicine also kill
many other species (*not visible*).
These helpful bacteria might grow
back — but they might not.


A key type of Actinobacteria
called Bifidobacteria is selectively
nourished by breast milk, so it's
no wonder these bacteria flourish
in the first few months. And it's
a good thing—they give a big
boost to the baby's digestive


What happens if...
I WAS BOTTLE-FED, NOT BREAST-FED?
Bottle-fed babies don't receive quite the same microbes as breast-fed babies and may have somewhat delayed immune development, more allergies and other health problems. But it's only


Rites of passage
Your microbiome is not only different from anyone else's, it's different at various stages of your life. The biggest shifts occur when you have a major change in diet. But adolescence, pregnancy and old age can also alter your microbiome. So can malnutrition, disease and antibiotic drugs.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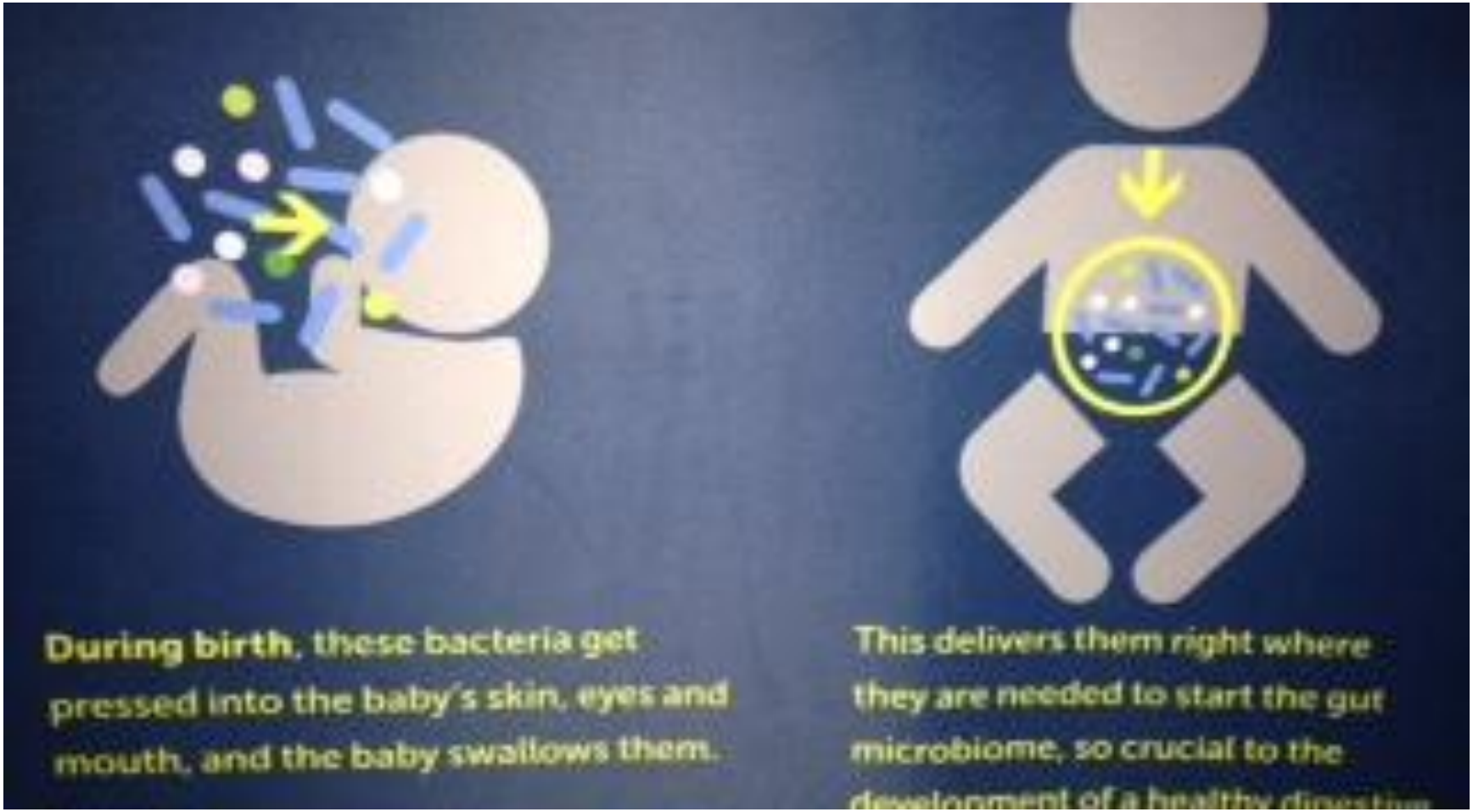
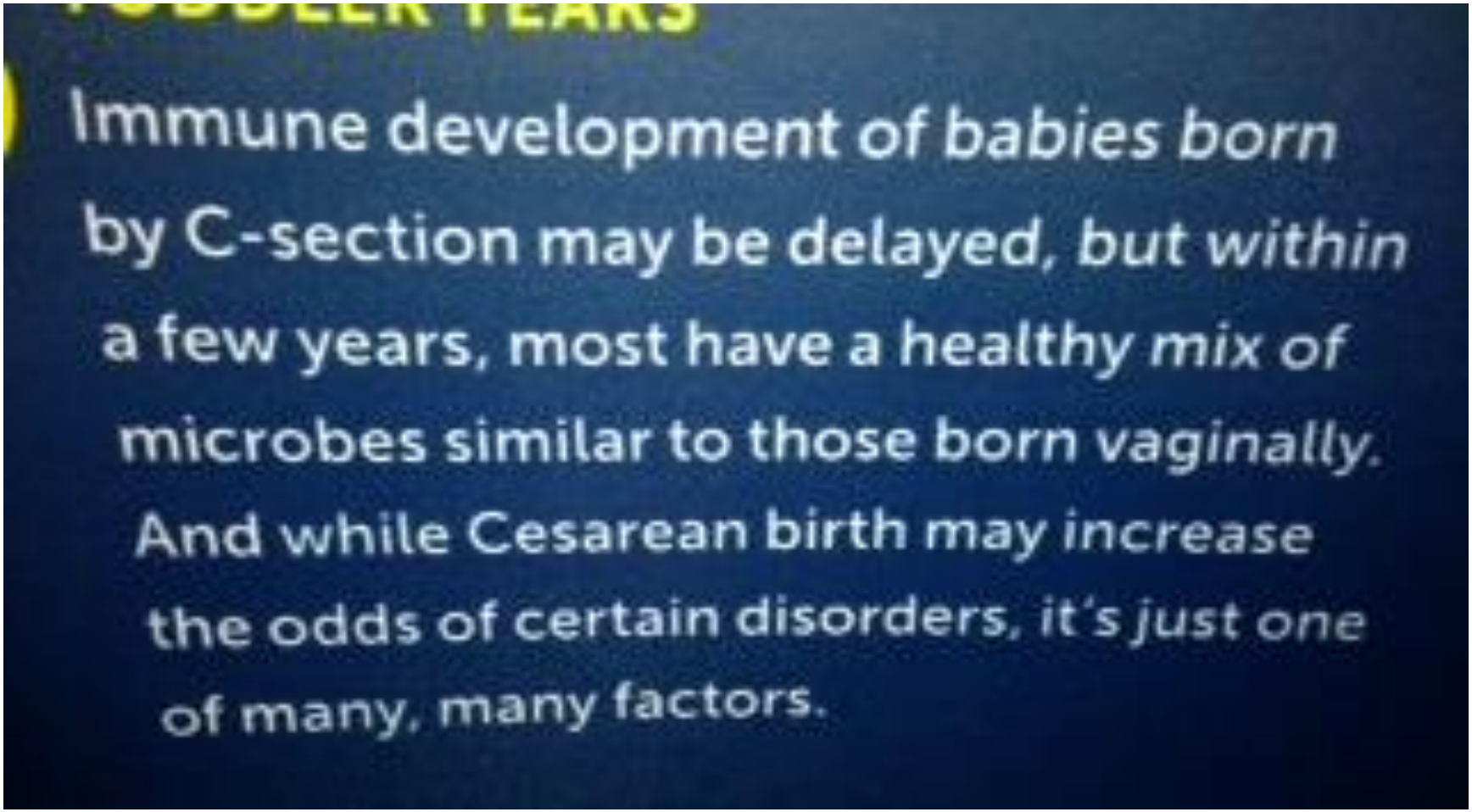
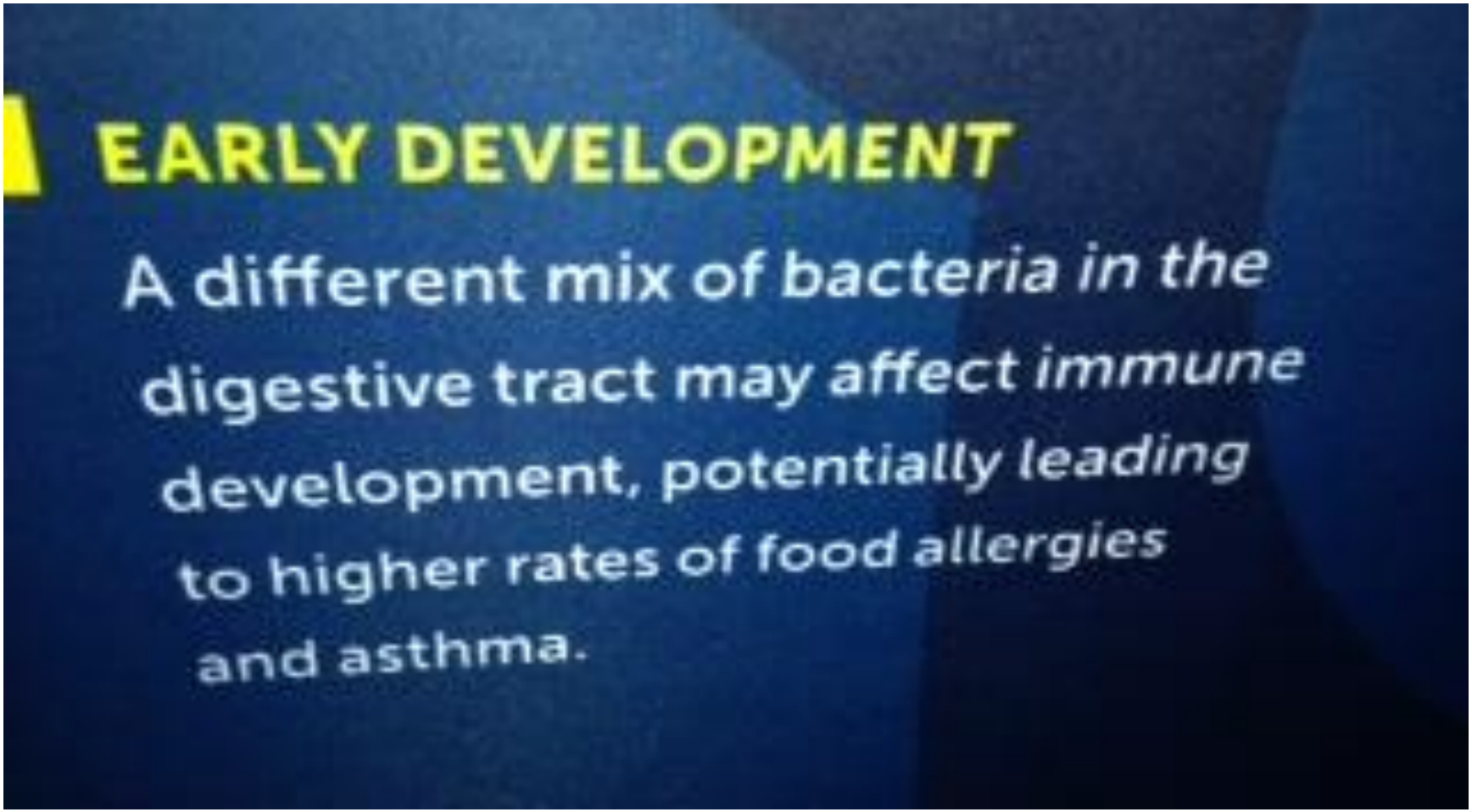

During birth, these bacteria get pressed into the baby's skin, eyes and mouth, and the baby swallows them.
This delivers them right where they are needed to start the gut microbiome, so crucial to the


Immune development of babies born
by C-section may be delayed, but within
a few years, most have a healthy mix of
microbes similar to those born vaginally.
And while Cesarean birth may increase
the odds of certain disorders, it's just one
of many, many factors.

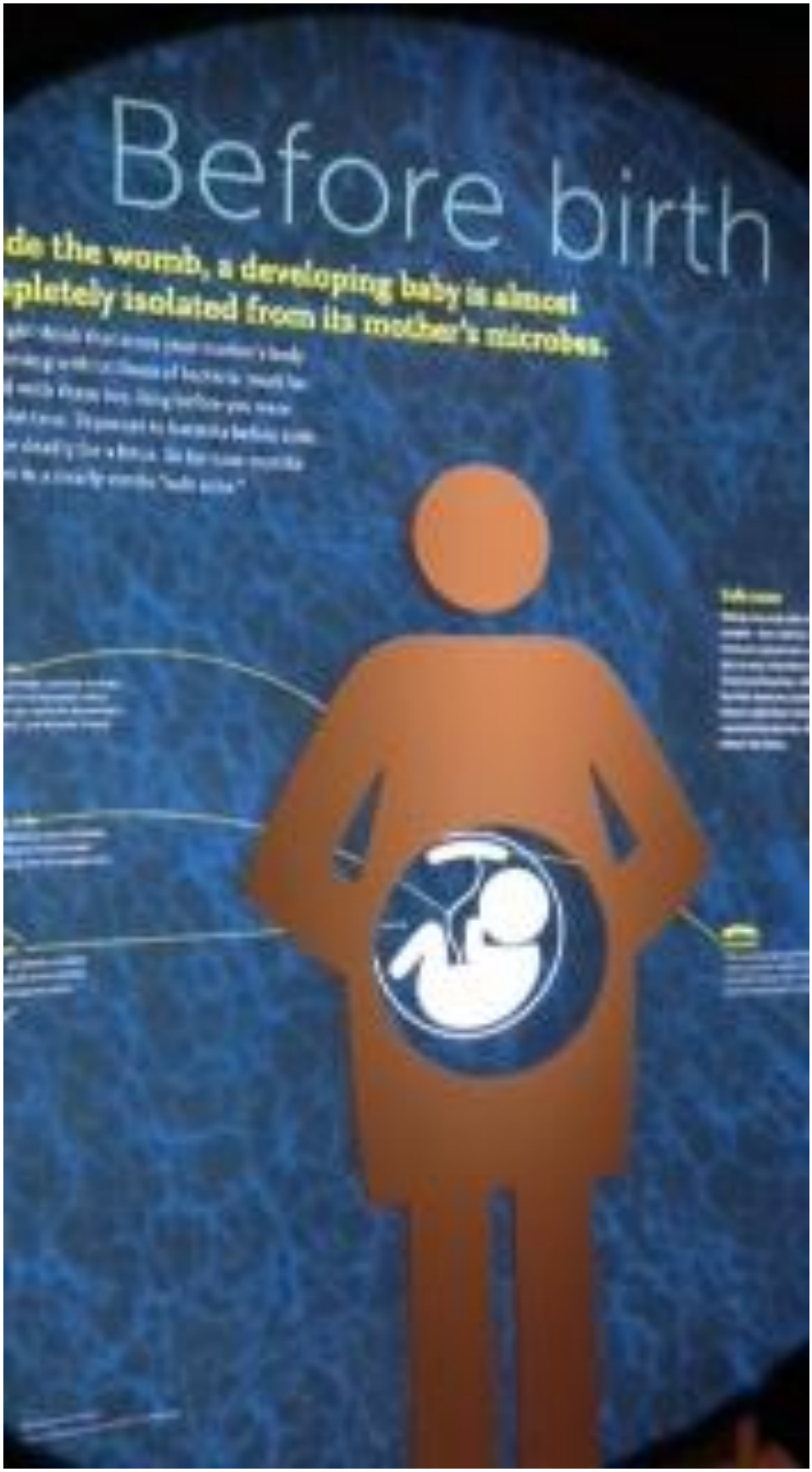

EARLY DEVELOPMENT
A different mix of bacteria in the digestive tract may affect immune development, potentially leading to higher rates of food allergies and asthma.


10%
Food for whom?
About 10 percent of all nutrients in breast milk cannot be digested by humans. But they don't go to waste: instead they feed helpful bacteria.

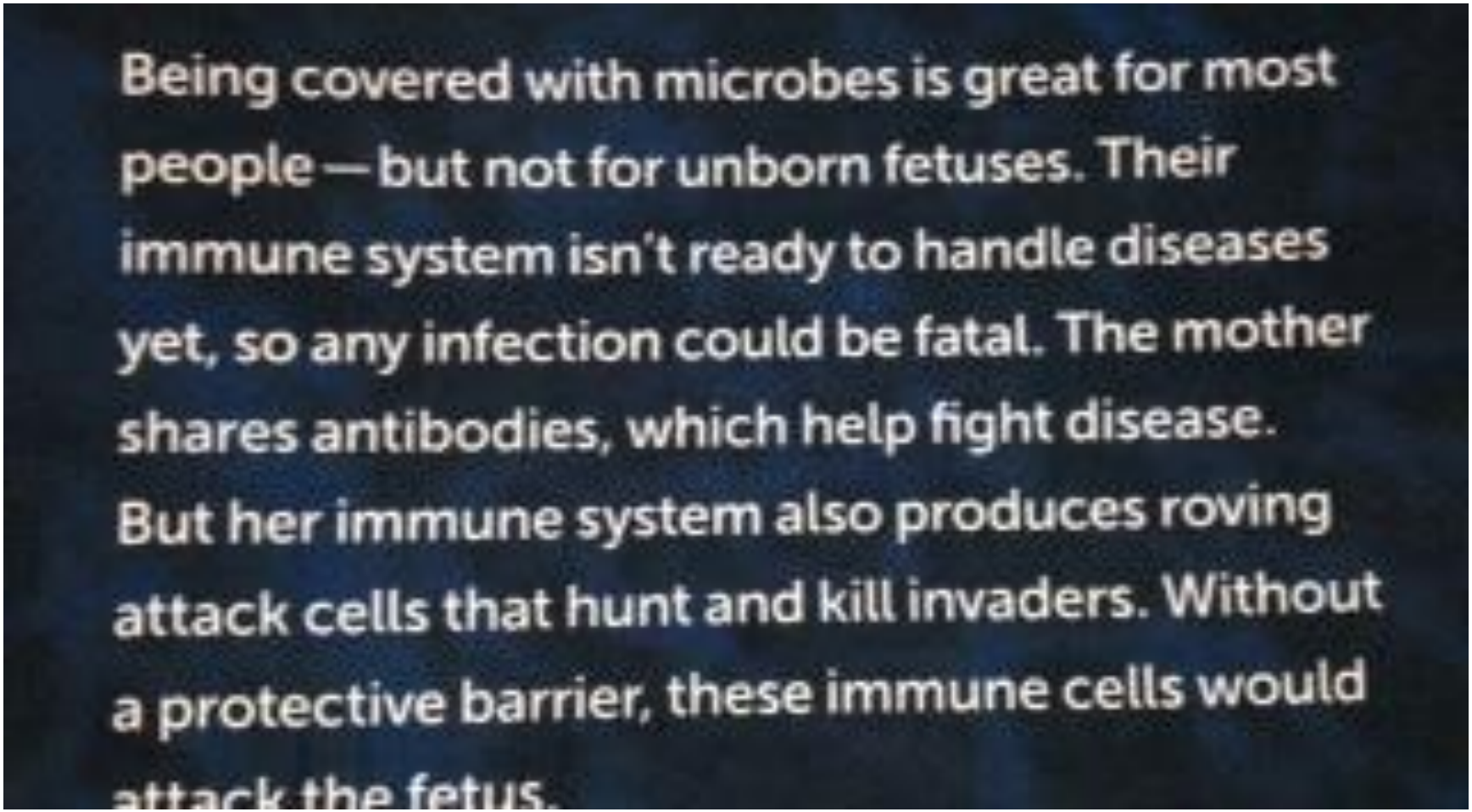
of bacteria that coat and protect the digestive tract and help train the immune system.

Breast milk serves as a "pathogen sponge" that prevents disease. Chemical decoys in breast milk mimic places where disease-causing microbes attack your body—so the pathogens stick to the milk molecules instead.

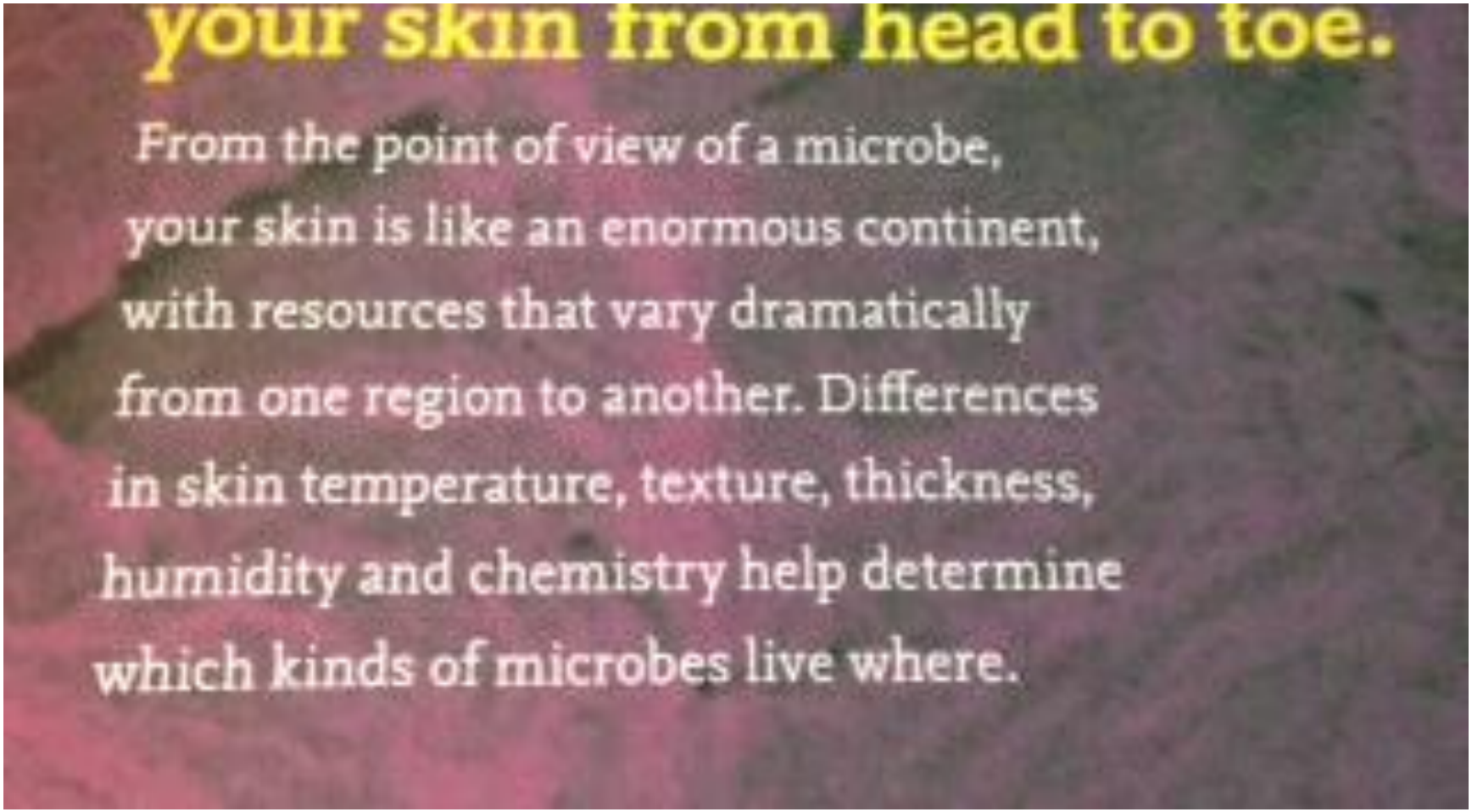
Before their first drink of milk, most babies already carry bacteria that digest milk—the *Lactobacillus* they picked

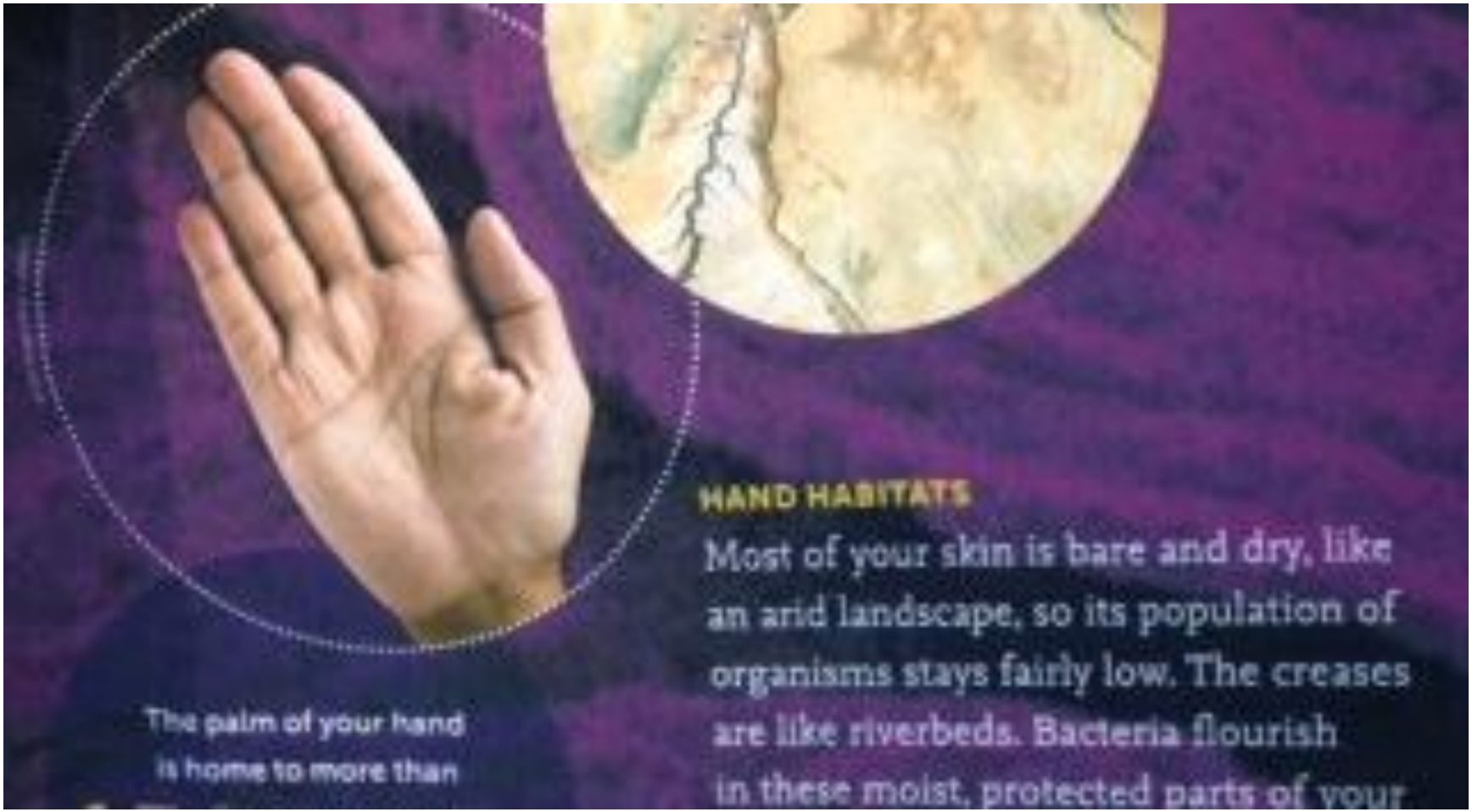

Before birth
de the womb, a developing baby is almost
pletely isolated from its mother's microbes.

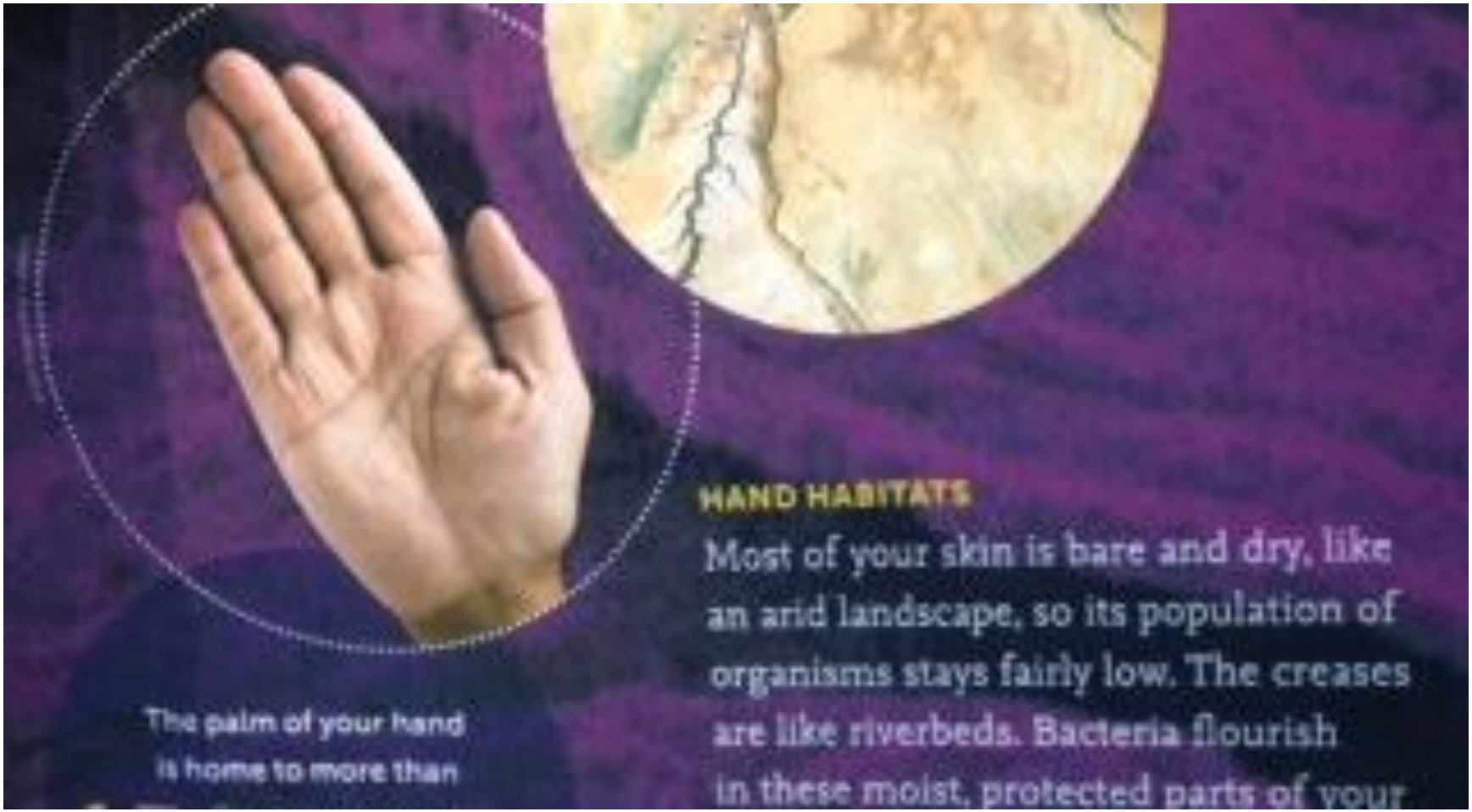
Safe ZOne


Being covered with microbes is great for most people — but not for unborn fetuses. Their immune system isn't ready to handle diseases yet, so any infection could be fatal. The mother shares antibodies, which help fight disease. But her immune system also produces roving attack cells that hunt and kill invaders. Without a protective barrier, these immune cells would attack the fetus.

Do microbes affect memory? They can in mice. Memory tests were given to two groups: normal mice, and sterile mice with no microbiome. Each was allowed to investigate a few objects for five minutes. Twenty minutes later, they returned, but some of the objects had changed. The normal mice focused on the new ones. The sterile mice spent equal time on each, as if they'd


your skin from head to toe.
From the point of view of a microbe, your skin is like an enormous continent, with resources that vary dramatically from one region to another. Differences in skin temperature, texture, thickness, humidity and chemistry help determine which kinds of microbes live where.


HAND HABITATS
Most of your skin is bare and dry, like an arid landscape, so its population of organisms stays fairly low. The creases are like riverbeds. Bacteria flourish in these moist, protected parts of your
The palm of your hand is home to more than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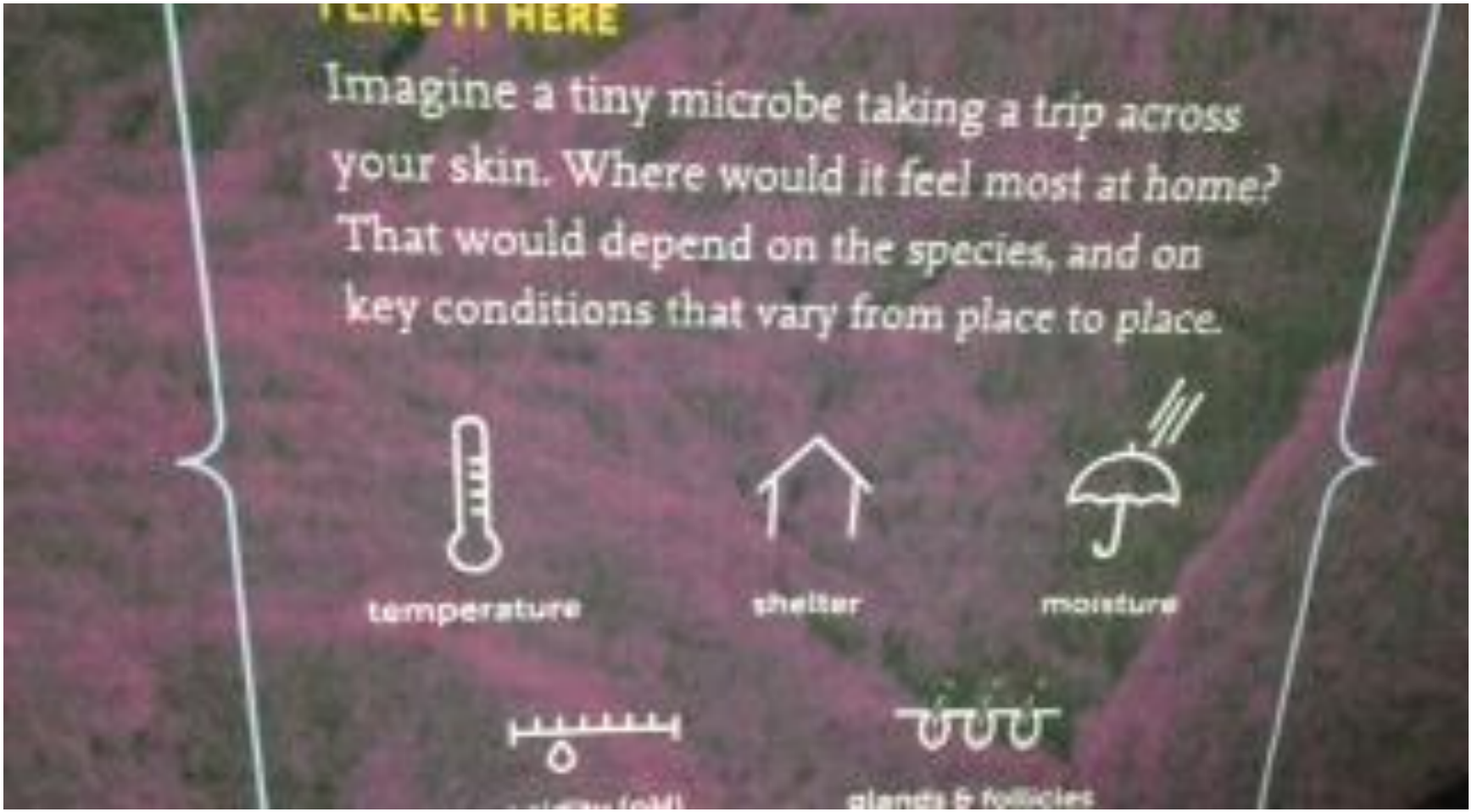
Imagine a tiny microbe taking a trip across your skin. Where would it feel most at home? That would depend on the species, and on key conditions that vary from place to place.
temperature
shelter
moisture


Bacteria are
alive
Bacteria are
small
Microbes are really small—too small to see without a microscope. Most are between 0.5 and 5 microns in length—roughly a thousandth of a millimeter.
Bacteria
move
Bacteria
consume
nutrients


communicate
swap genes
Bacteria
reproduce
Bacteria
evolve