



*Early Life
Organization:*

Mother's Milk
as Food & Signal

Katie Hinde

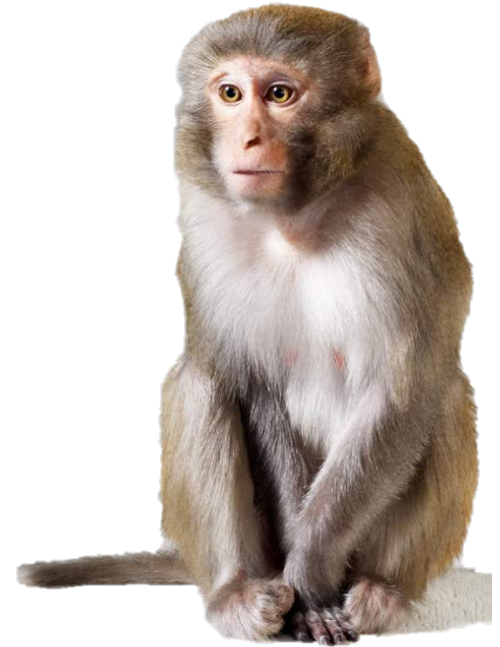
Center for Evolution and Medicine
School of Human Evolution and Social Change
Arizona State University

 @Mammals_Suck

mammalssuck.blogspot.com

photo by Kathy West

In socially complex species, how does one become a competent adult?



Developmental “Bottlenecks”



Fetus

Infant

Juvenile

Adult

Physiological
Investment



Behavioral
Care



Fetus



Infant

Physiological
Investment



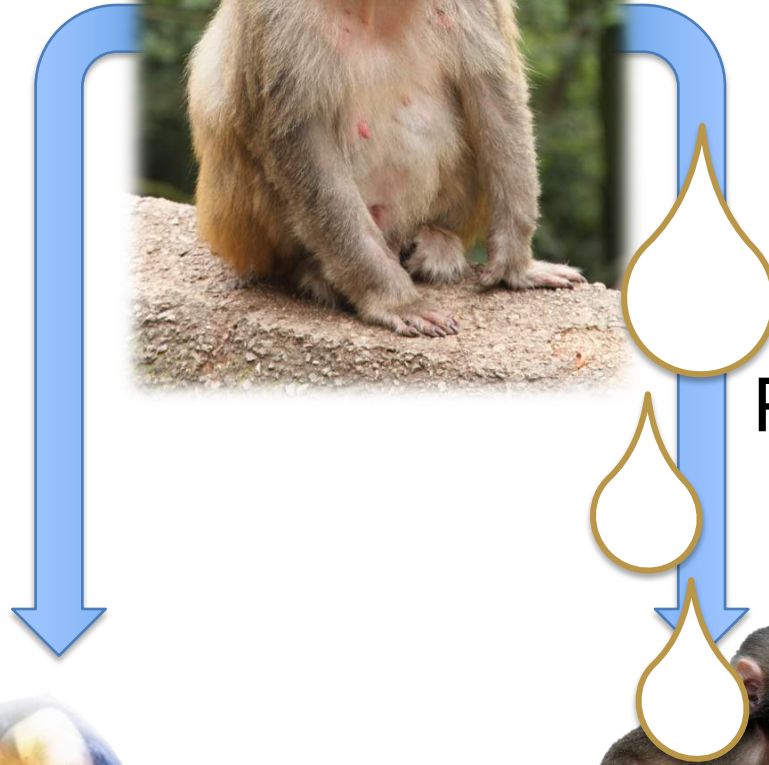
Behavioral
Care
&
Physiological
Investment



Fetus



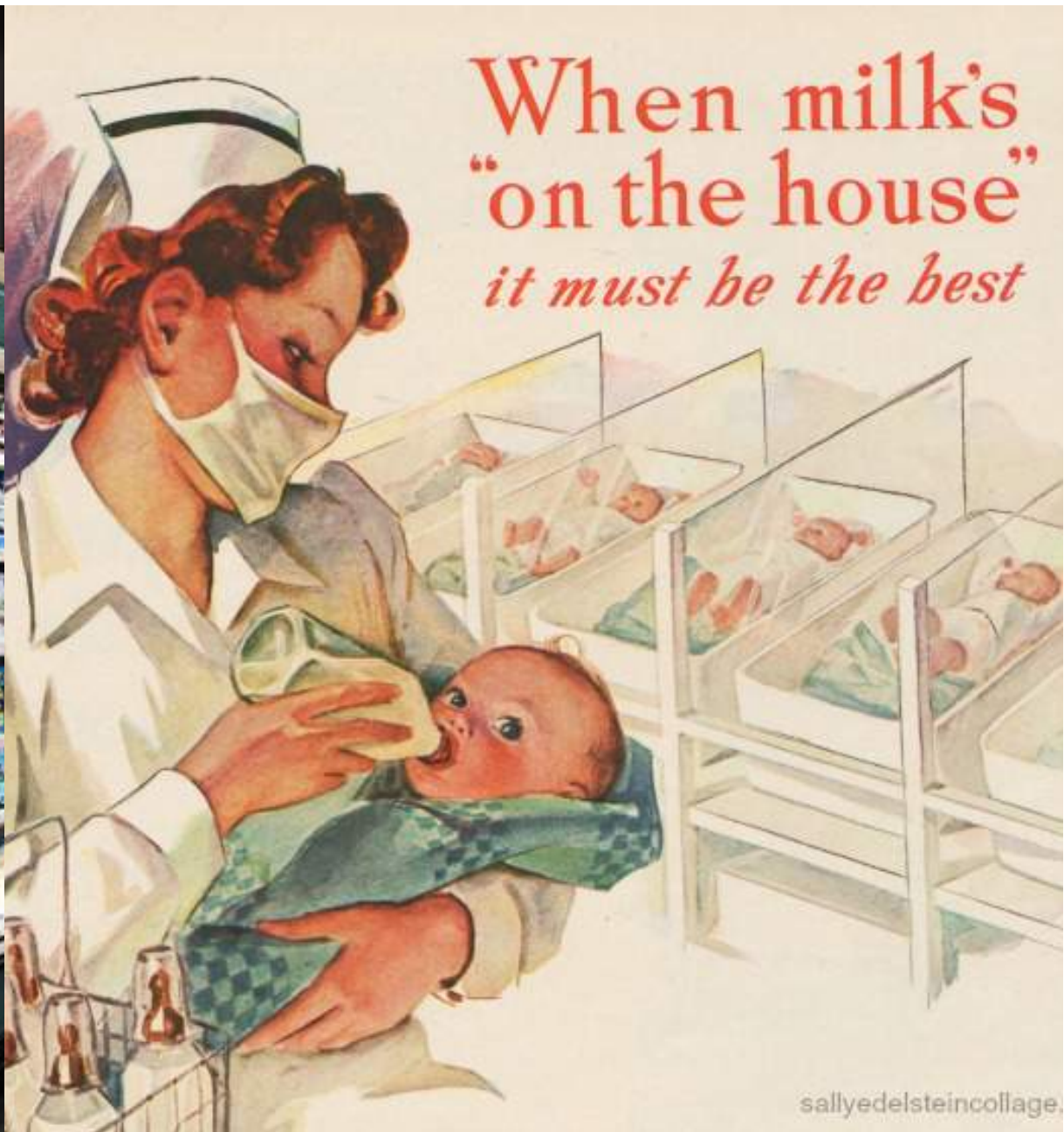
Infant



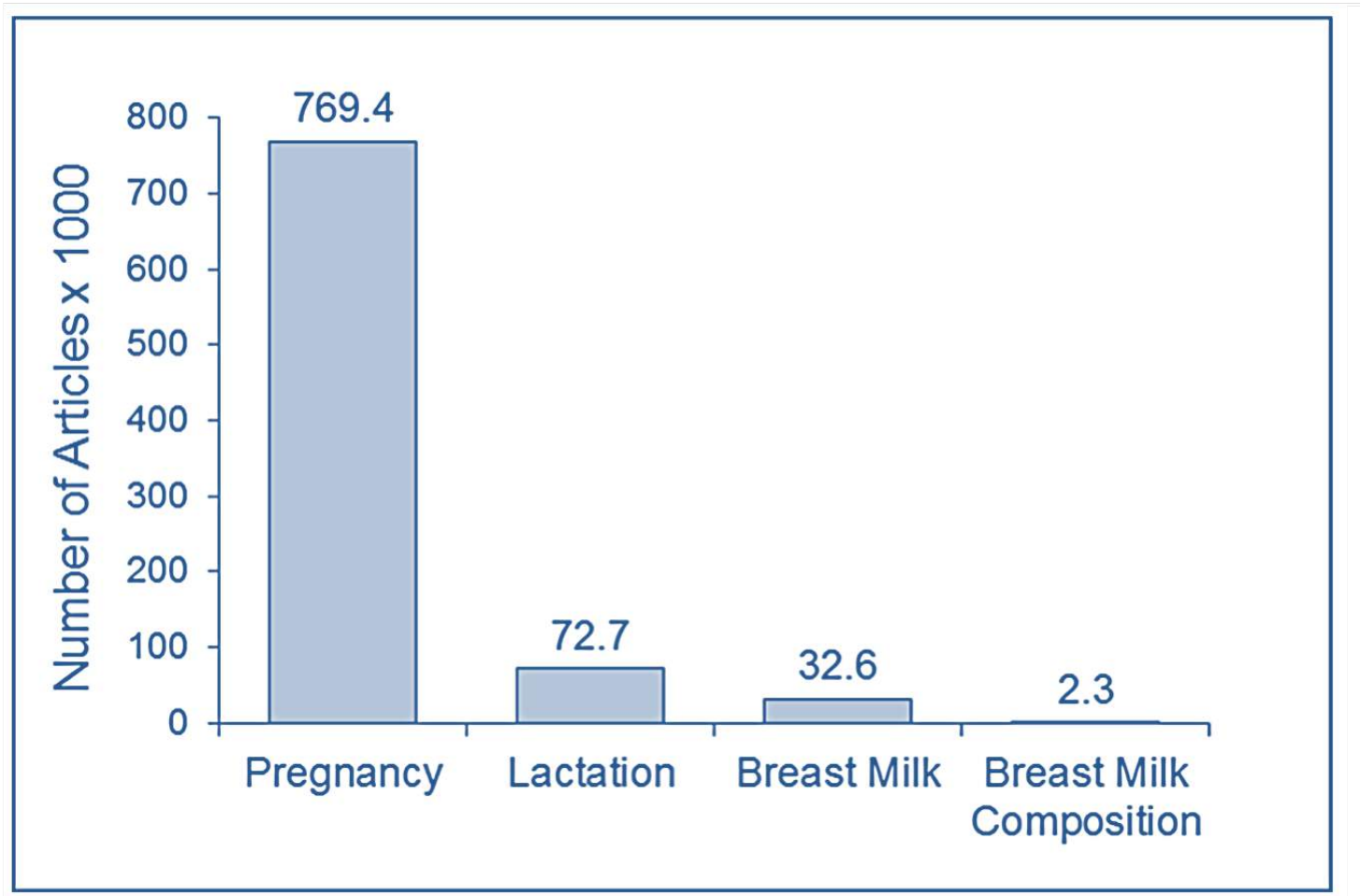


Pretenders to the Throne



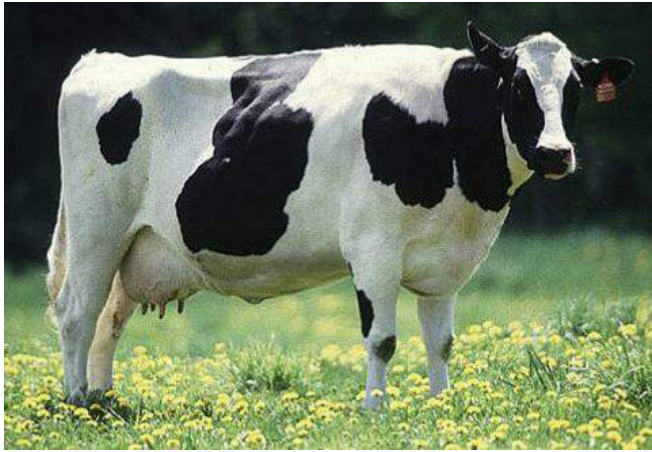


PubMed Key Word Search



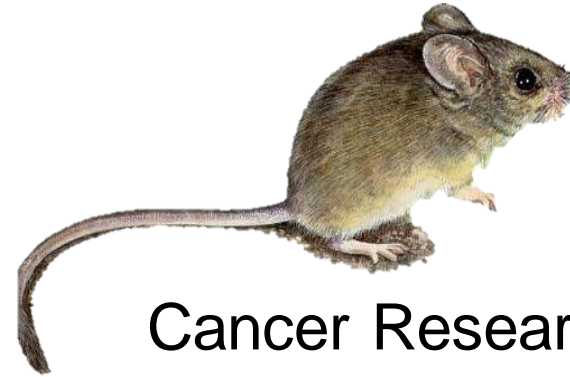
Hinde K. 2015. Motherhood. in: Emerging Trends in the Social and Behavioral Sciences

Super-Function



Dairy Science

Dysfunction



Cancer Research

Pseudo-Functional Substitutes



Breast Milk Feeding vs.
Formula-feeding

Function



Behavioral Biology
of Lactation

MILK:

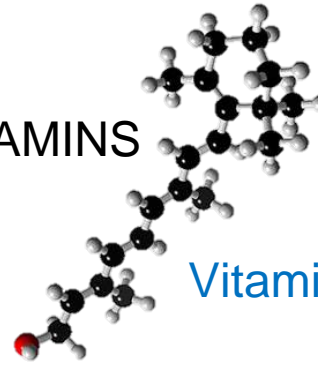


ENERGY



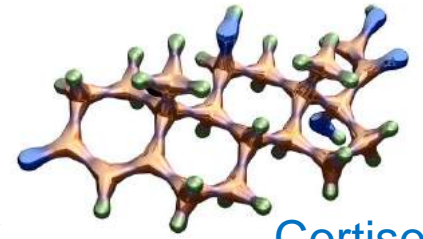
Milk Fat Globule

VITAMINS



Vitamin A

HORMONES



Cortisol

MINERALS



BACTERIA

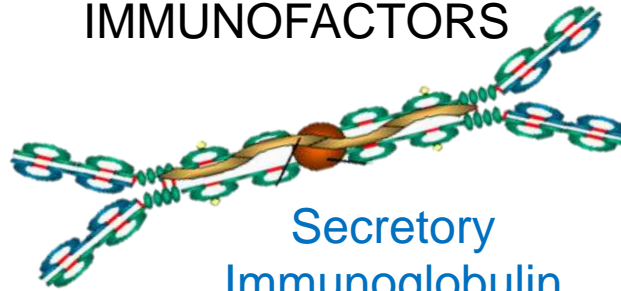


Lactobaccilli

WATER

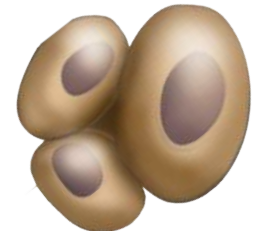


IMMUNOFACTORS



Secretory Immunoglobulin

STEM CELLS & miRNA



THOUSANDS OF CONSTITUENTS!



Signal

Mothers are not all the same.



Infants are not all the same.

MOTHER'S MILK

SOURCES of VARIATION

Life History
Nutrition
Health
Condition



Animal Model Systems

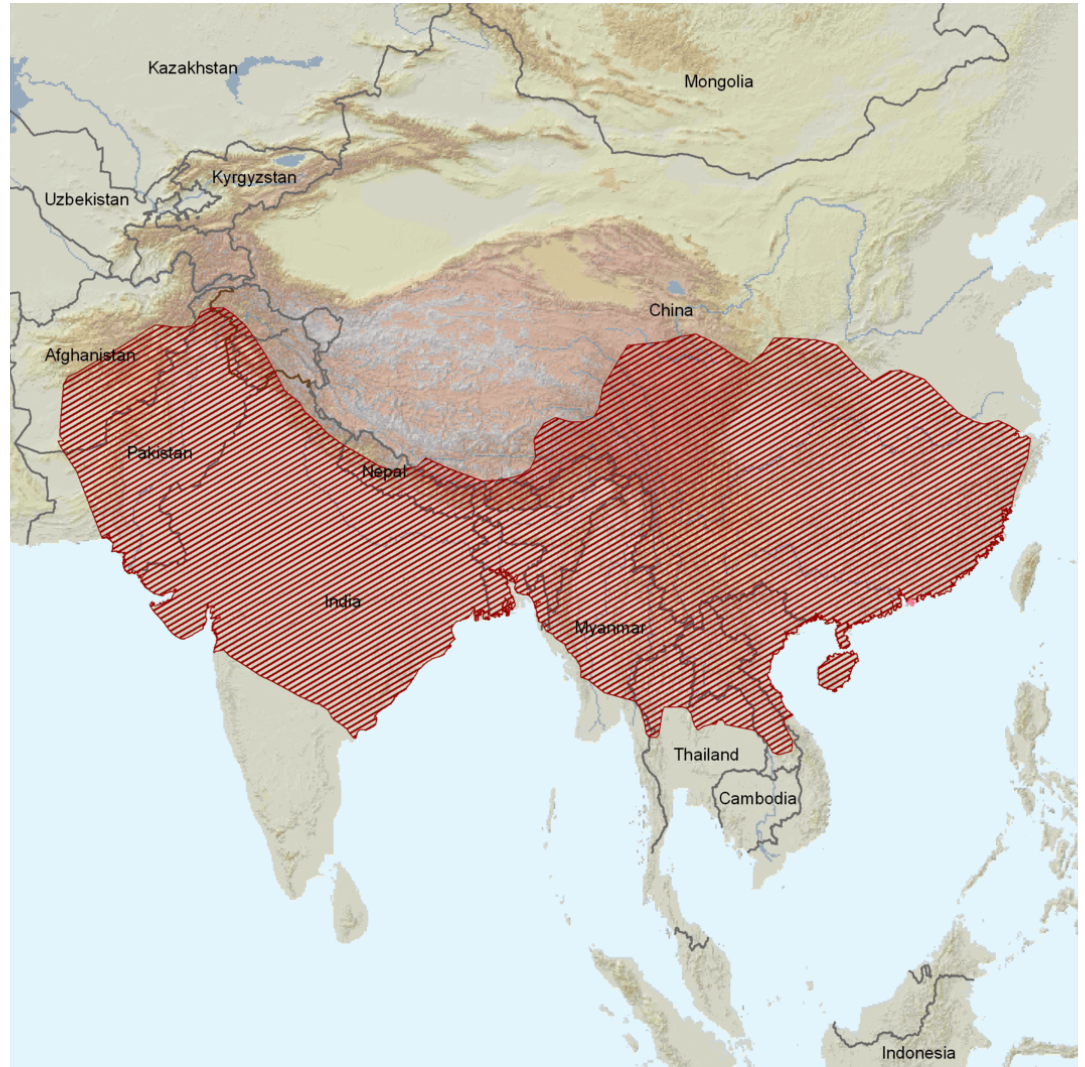
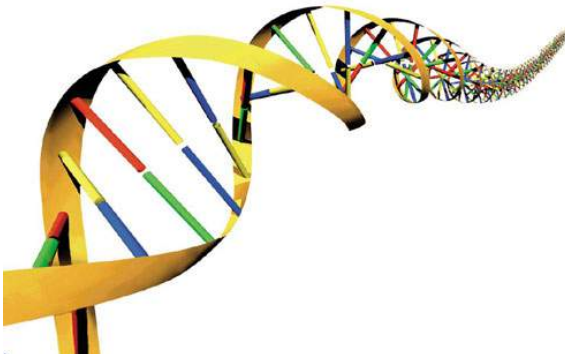
MAGNITUDE of VARIATION

Nutrients
Hormones
Bacteria
Immune Factors
Stem Cells

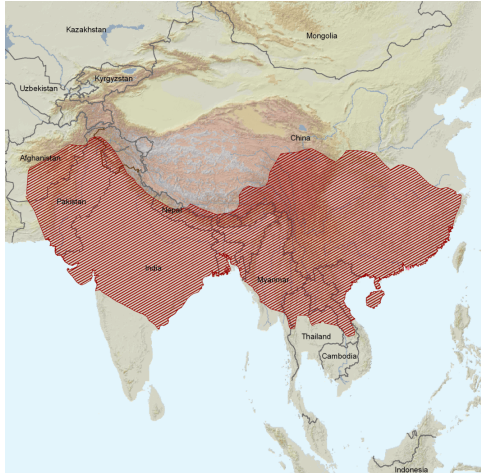
CONSEQUENCES of VARIATION

Growth & Development
Behavior & Temperament
Immune Function
Cognition
Bacterial Colonization

The Noble Rhesus Macaque



Rhesus Ecosystems



Rhesus Ecosystems

NEW DELHI JOURNAL

Monkeys in the Parks, Monkeys in the Palace



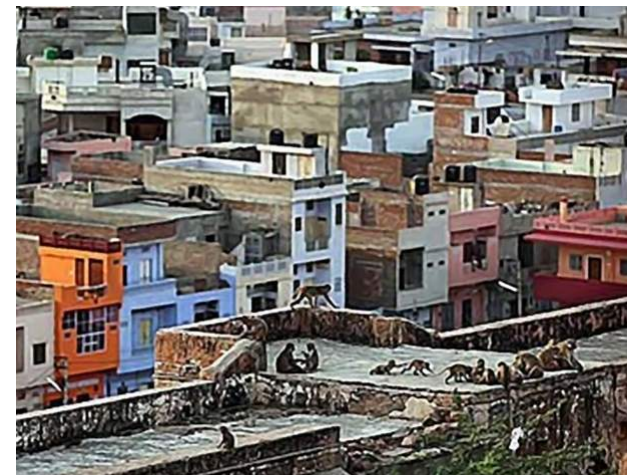
Manpreet Romana/Agence France-Presse — Getty Images

A park scene illustrates a problem in New Delhi: As people push local monkeys out, the monkeys push, and sometimes bite, back.


By AMELIA GENTLEMAN

Published: November 14, 2007

NEW DELHI, Nov. 13 — The authorities here managed to do very little about the city's soaring wild monkey population — until the deputy mayor toppled from his terrace to his death as he tried to fend off a gang of the animals.



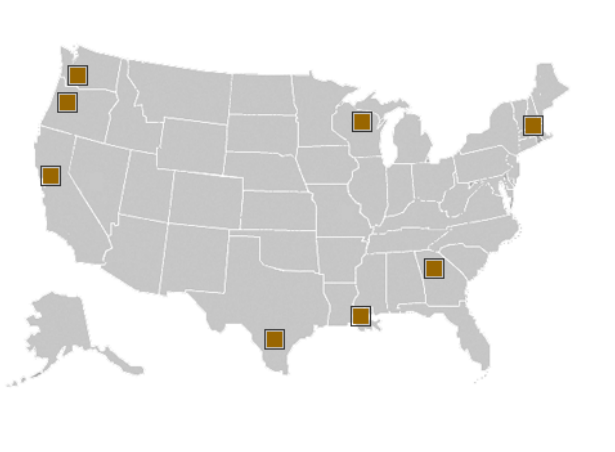
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E-MAIL OR SAVE
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 PRINT

 REPRINTS

Comparative Lactation Lab 2005-Present California National Primate Research Center



0.2 hectare corrals

California National Primate Research Center



photo by Kathy West

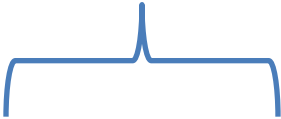


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photo by our Google Overlord

Rhesus Macaques: Seasonal Breeders

Breeding
Season



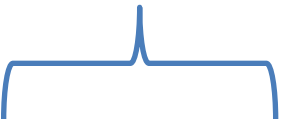
Sept-Dec



Pregnancy
5.5 Mo



Birth
Season



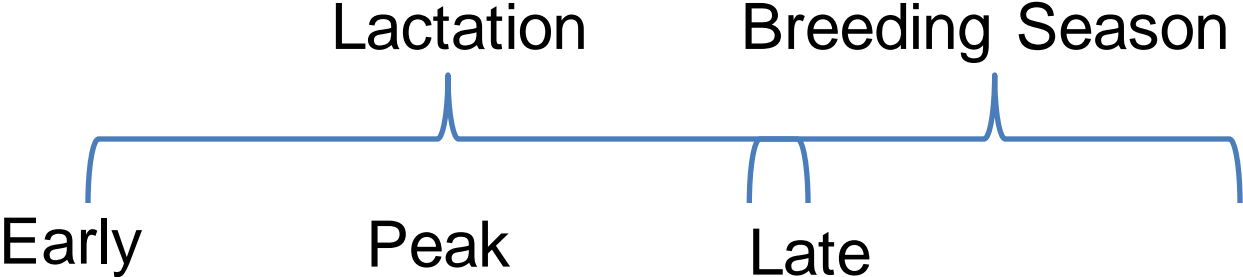
March-June



Lactation
~8-10 Mo



Rhesus Macaques: Seasonal Breeders



1Mo.



3-4 Mo.



5-6 Mo.



Mother's Milk & Infant Organization

photo by Kathy West

BEHAVIORAL ACTIVITY



Mother-Infant Interactions

BEHAVIORAL ACTIVITY



Exploration

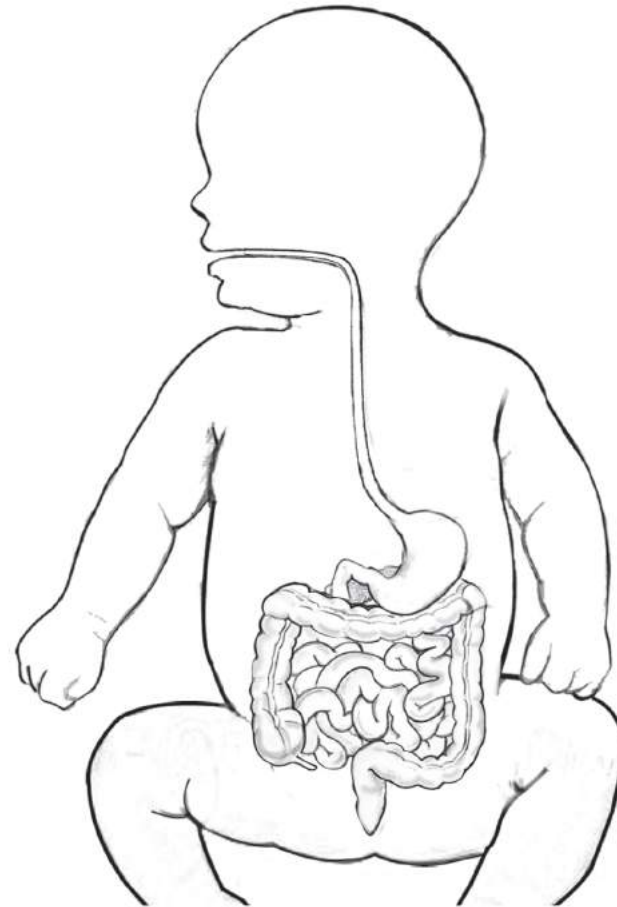
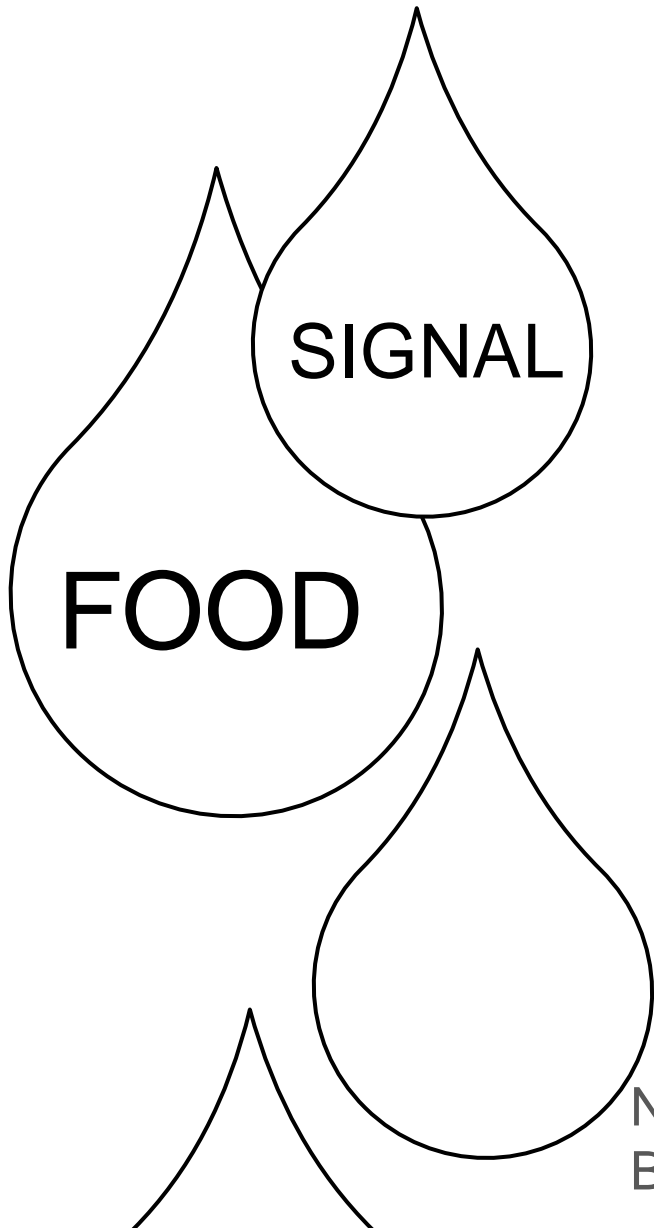
BEHAVIORAL ACTIVITY



Social Experience (Playing)



Integrative Lactation Biology



Neville et al. 2012 MGB; Hinde et al. 2015;
Bernstein & Hinde 2016 AJP; Donovan et al. 2014

Mother's Milk & Temperament



rhesus: Hinde & Capitanio 2010 AJP, Sullivan et al. 2011 J Dev Psychobiol, human: Grey et al. 2013 PNEC
rats: Angelucci et al. 1983, 1985, Cataloni et al. 1993, 2000, 2002, Casolini et al. 1997

Angelucci, Catalani, & Casolini Research Group
Department of Human Physiology and Pharmacology
University of Rome

1983-Present



Angelucci, Catalani, & Casolini Research Group
Department of Human Physiology and Pharmacology
University of Rome

1983-Present

Glucocorticoids in Dam's H₂O



Glucocorticoids in Milk

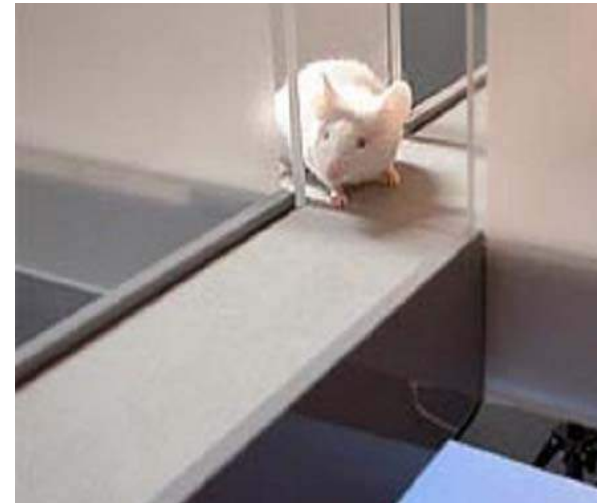
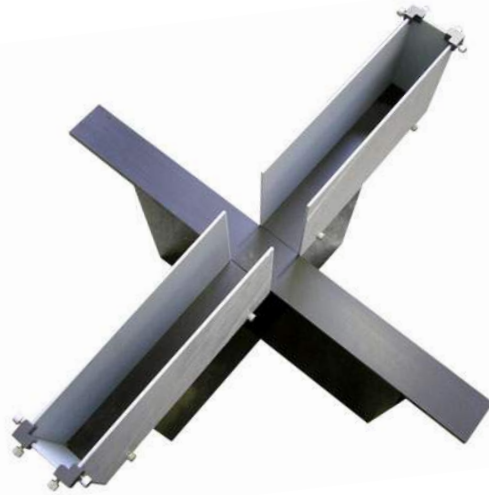


Angelucci, Catalani, & Casolini Research Group
Department of Human Physiology and Pharmacology
University of Rome

1983-Present

As adults, rats exposed to milk corticosterone as pups:

- Less behavioral inhibition, more exploration in novel setting



As adults, **males** exposed to milk corticosterone as pups:

- Increased glucocorticoid receptor density in their hippocampus

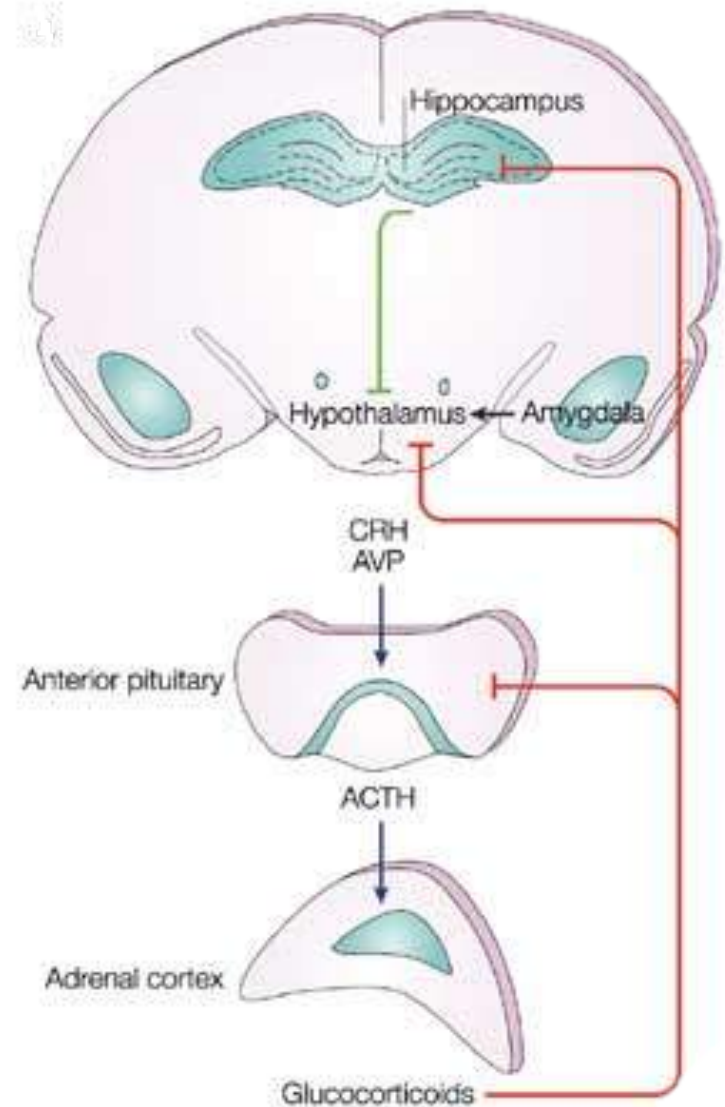
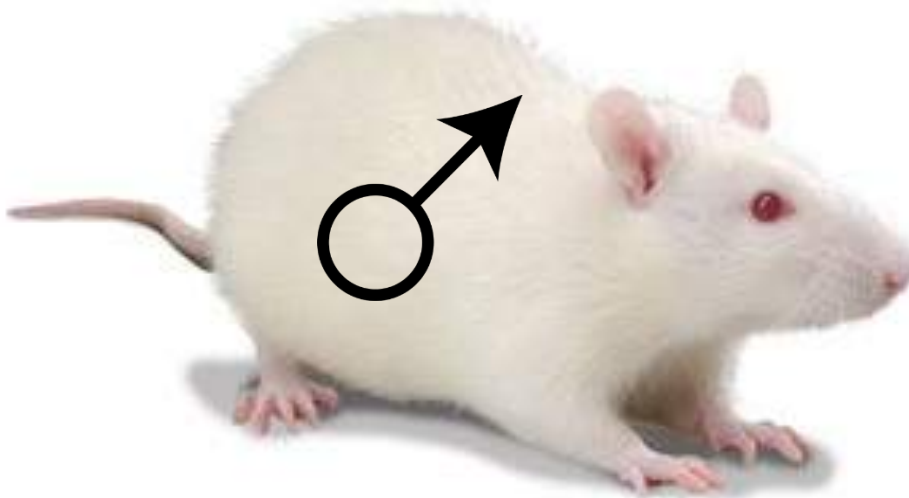
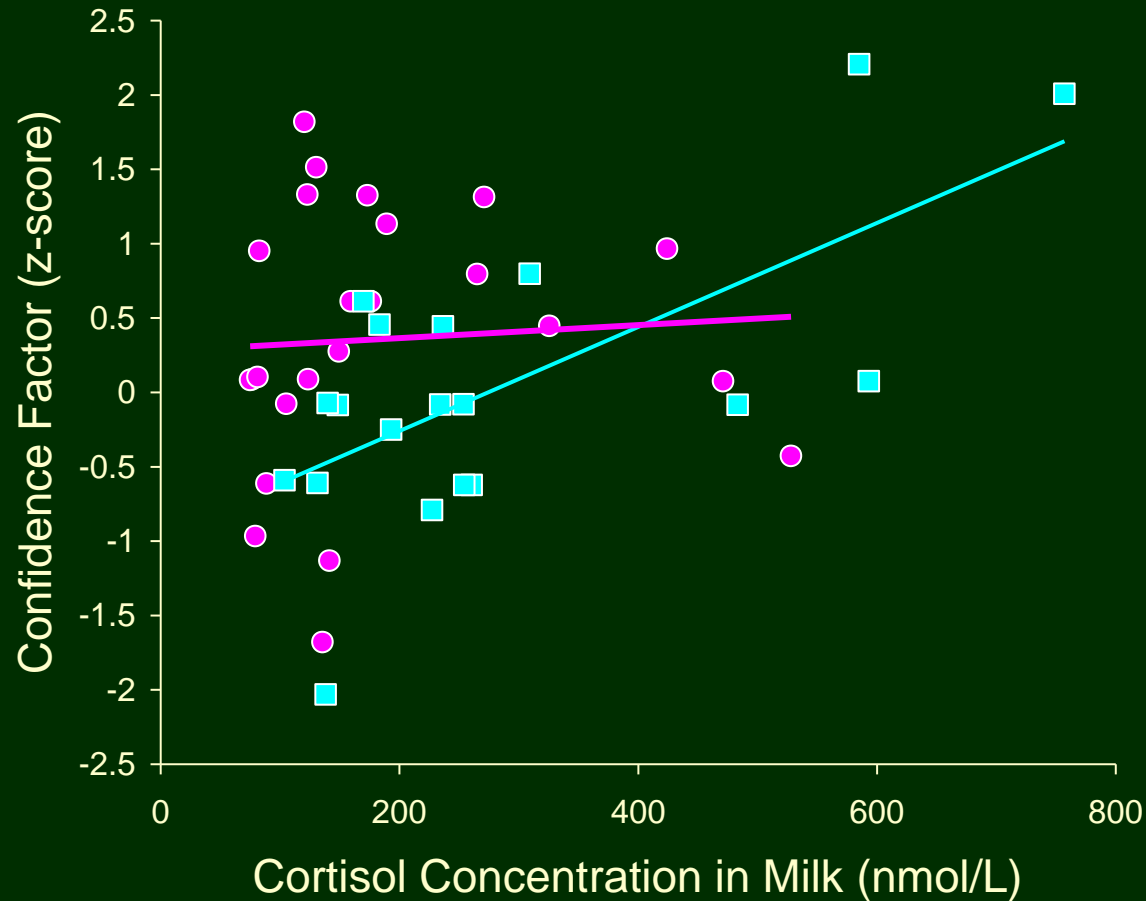


Fig. Sandi et al. 2004 *Nature Neurosci Rev*

Milk Cortisol Associated w/ Confidence in Rhesus



Sons ($p < 0.002$)
Daughters (NS)

for Sons

Sullivan et al. *Dev Psychobiol* 2011, N=44

Milk Cortisol Associated w/ Temperament in Humans



Higher concentrations of cortisol in milk associated with “Negative Affect”

- fear
- sadness
- discomfort
- anger/frustration
- reduced soothability

for Daughters



Milk Glucocorticoids

- Investigated in Isolation
- Cortisol correlated with milk
 - fat %
 - protein %
 - volume
- Cortisol regulates digestion, energy use, and other metabolic processes

Sullivan et al. *Dev Psychobiol* 2011, Hinde *Building Babies* 2013
Akers "Lactation and the Mammary Gland" 2002

Infant BioBehavioral Assessment



- 3-4 Months of Age
- Removed from Social Group for 25 hours
- Components of BBA
 - Intruder Challenge
 - Video Playback
 - HPA-axis Regulation
 - Behavioral Observations
 - Temperament Ratings**

Infant BioBehavioral Assessment

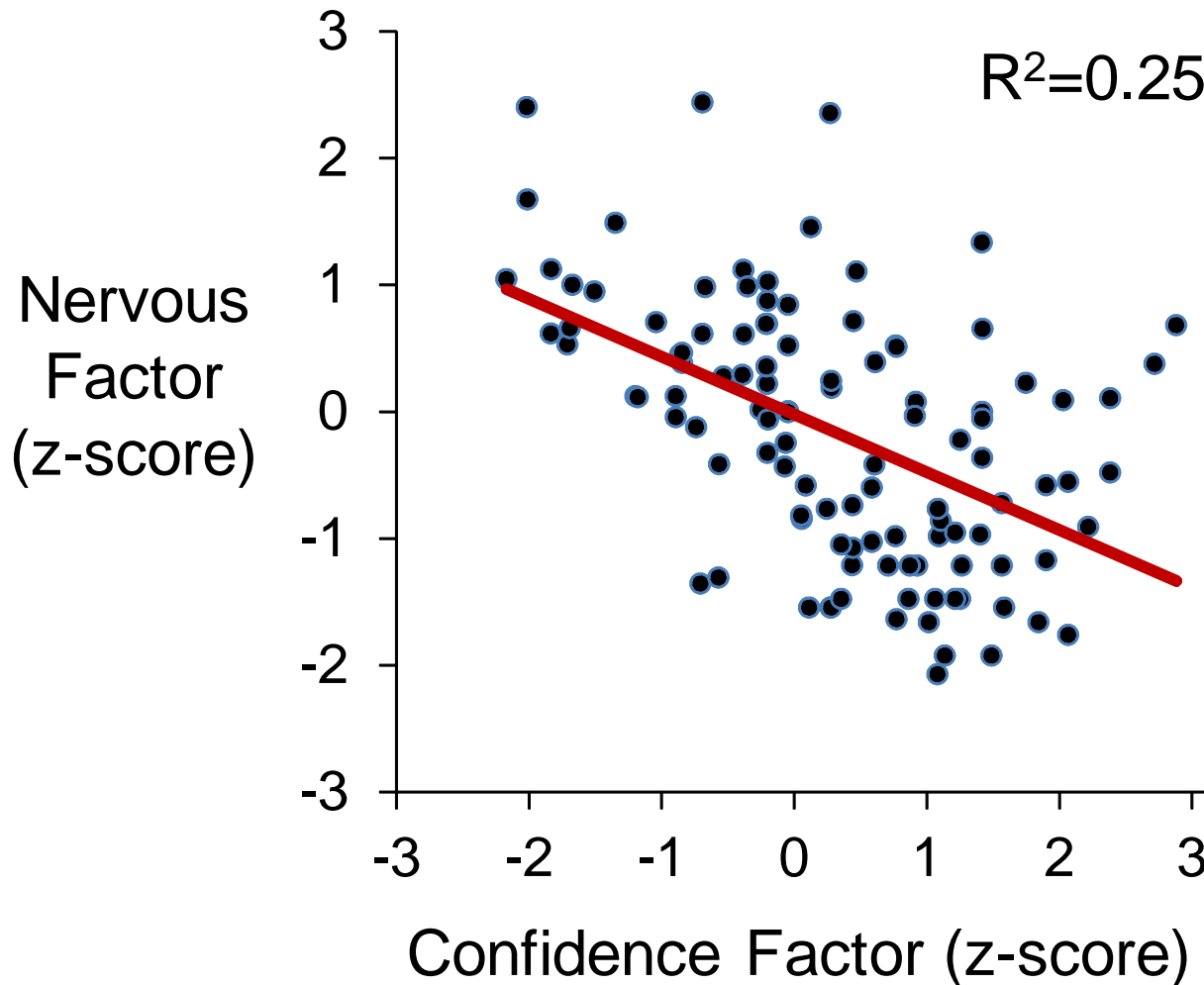


- Temperament ratings of 16 trait adjectives:

Depressed	Vigilant	Playful
Tense	Timid	Confident
Gentle	Calm	Curious
Nervous	Fearful	Active
Flexible	Slow	Bold
Aggressive		

CONFIDENT: confident, bold, active, curious, playful
NERVOUS: nervous, fearful, timid, NOT calm,
NOT confident

Nervous & Confident Factors are Negatively Correlated



- CONFIDENT:**
confident
bold
active
curious
playful
- NERVOUS:**
nervous
fearful
timid
NOT calm
NOT confident

N=108

Lactation

Early

Peak

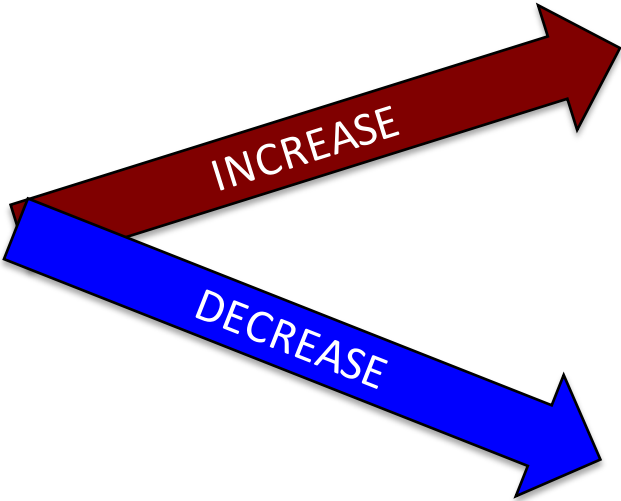
1 Mo.



3-4 Mo.



“Baseline”
Cortisol
Concentrations
in Milk



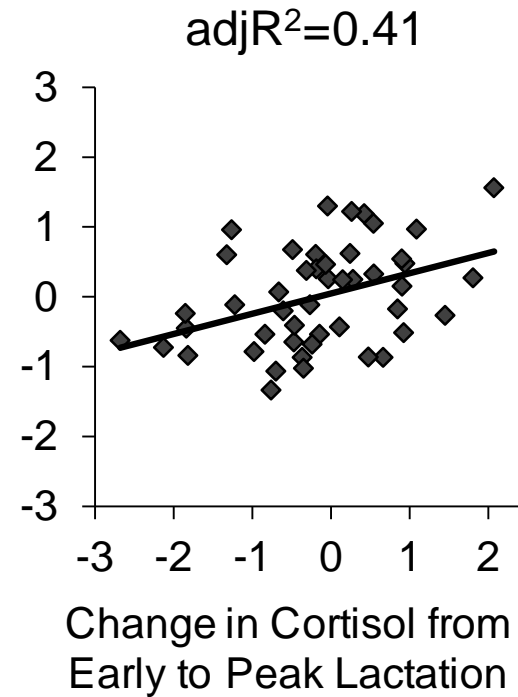
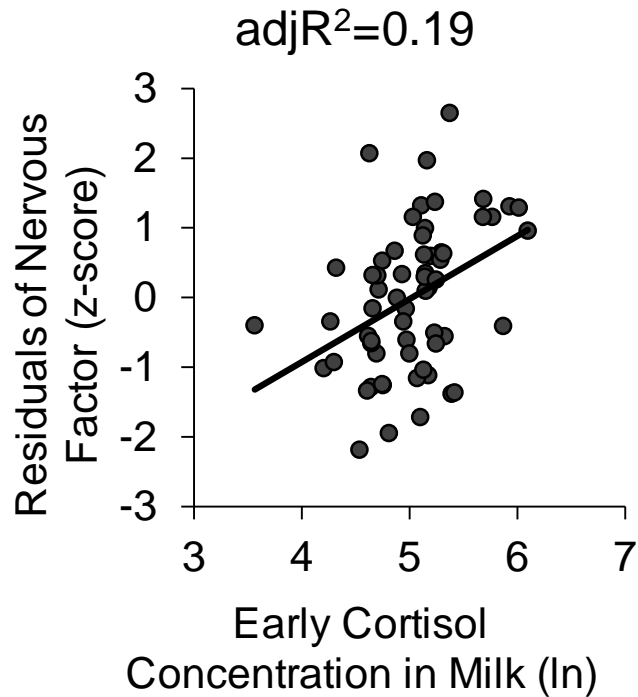
More Nervous
Less Confident

More Confident
Less Nervous

Covariates: primiparity, infant mass, available milk energy

SEX DIFFERENTIATED EFFECTS

NERVOUS



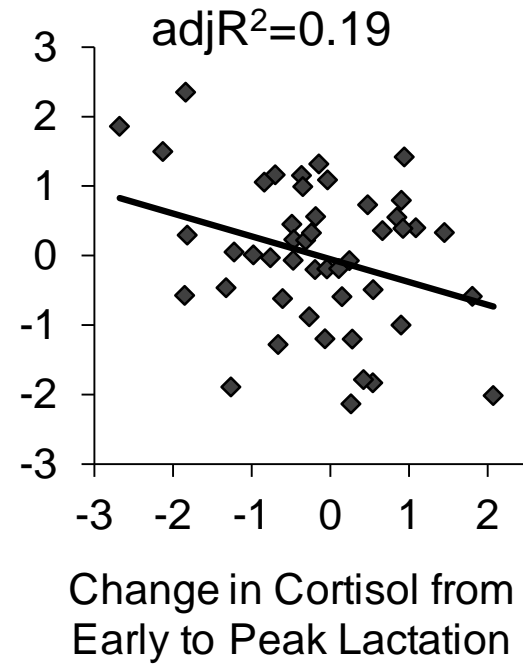
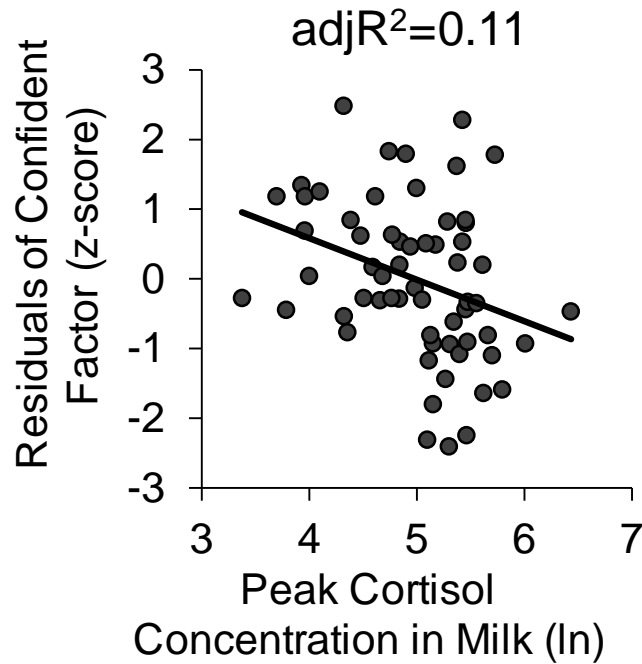
N=61



N=47

SEX DIFFERENTIATED EFFECTS

CONFIDENCE

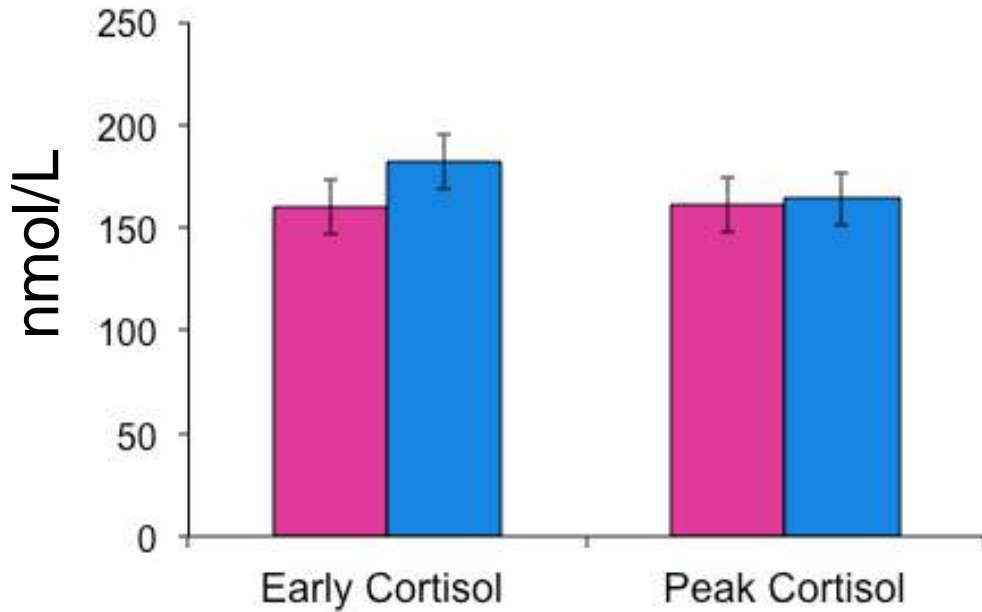


N=61



N=47

SEX-DIFFERENTIATED SENSITIVITY

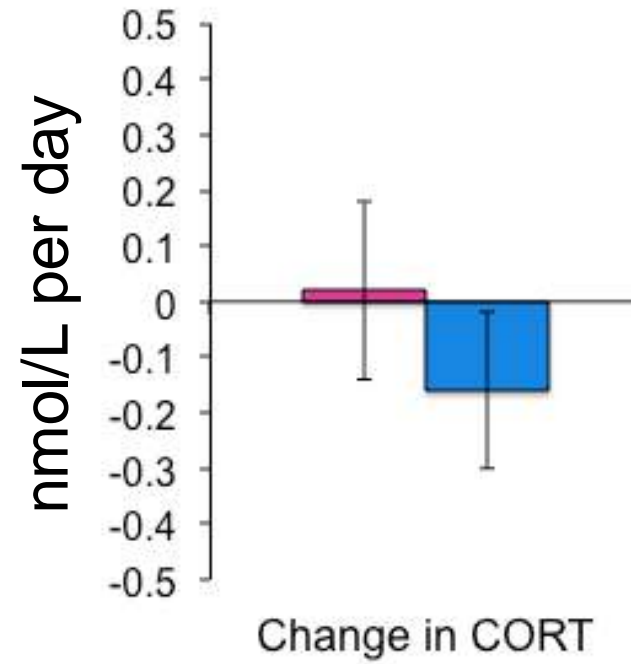
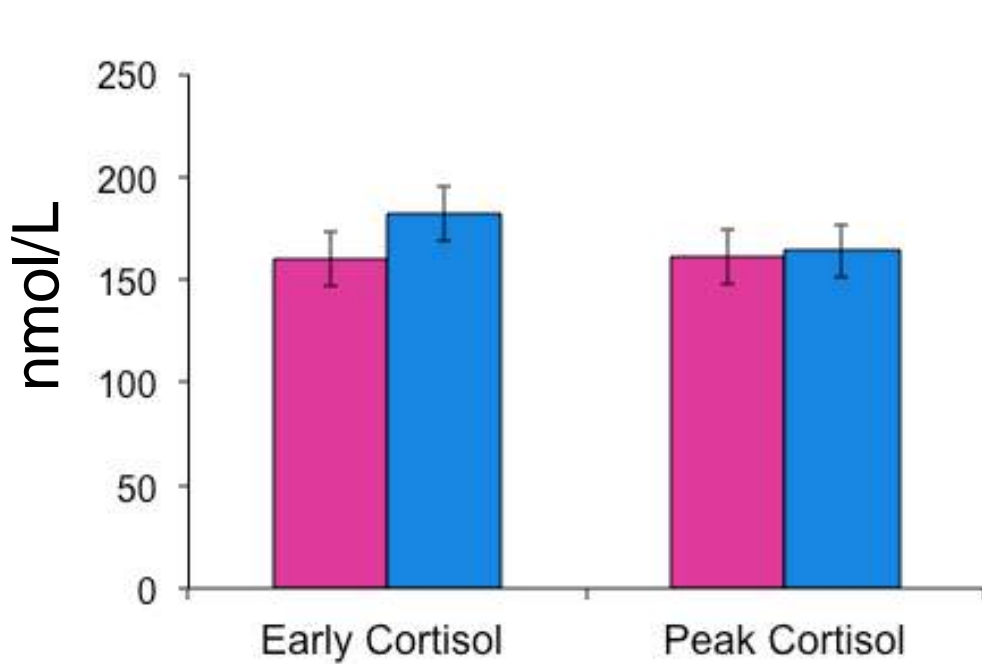


N=61



N=47

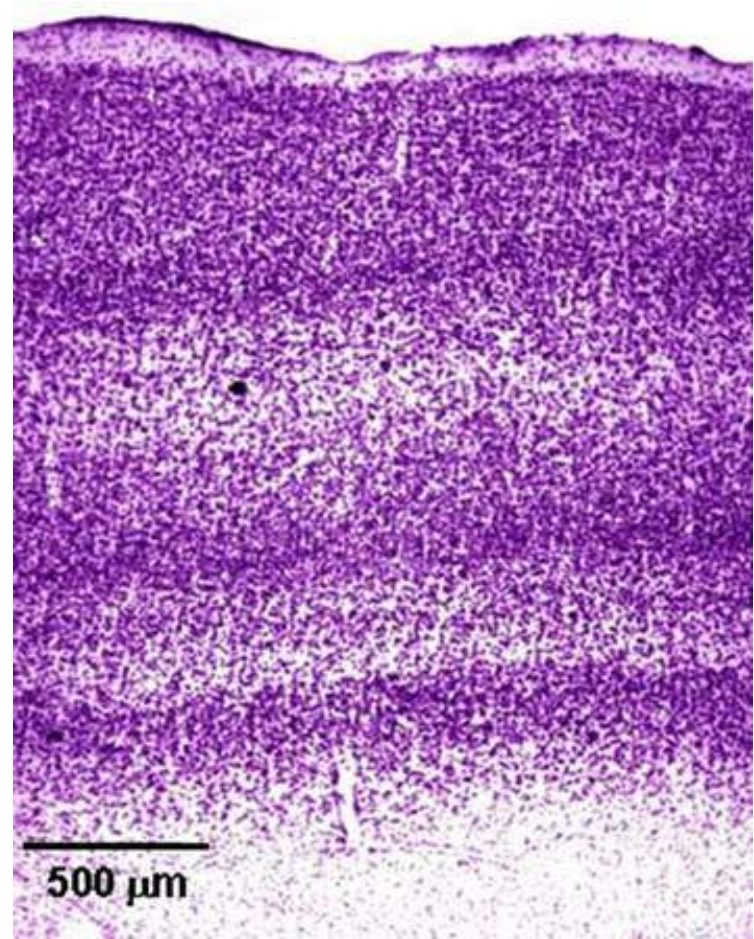
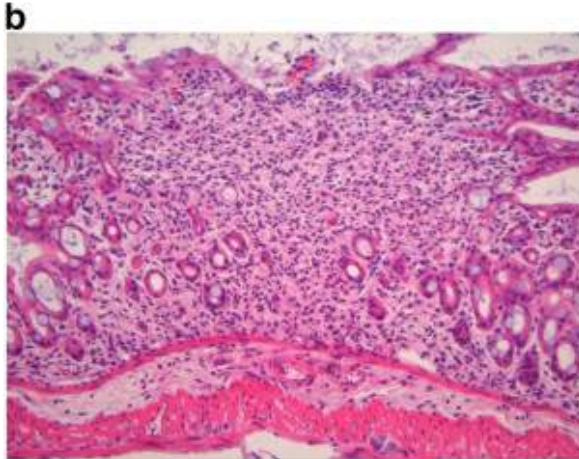
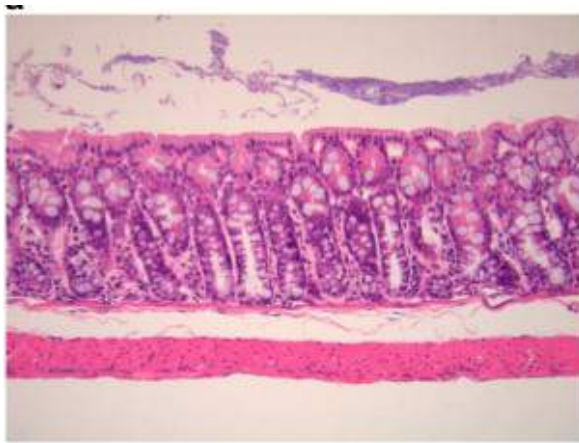
SEX-DIFFERENTIATED SENSITIVITY



N=61



N=47

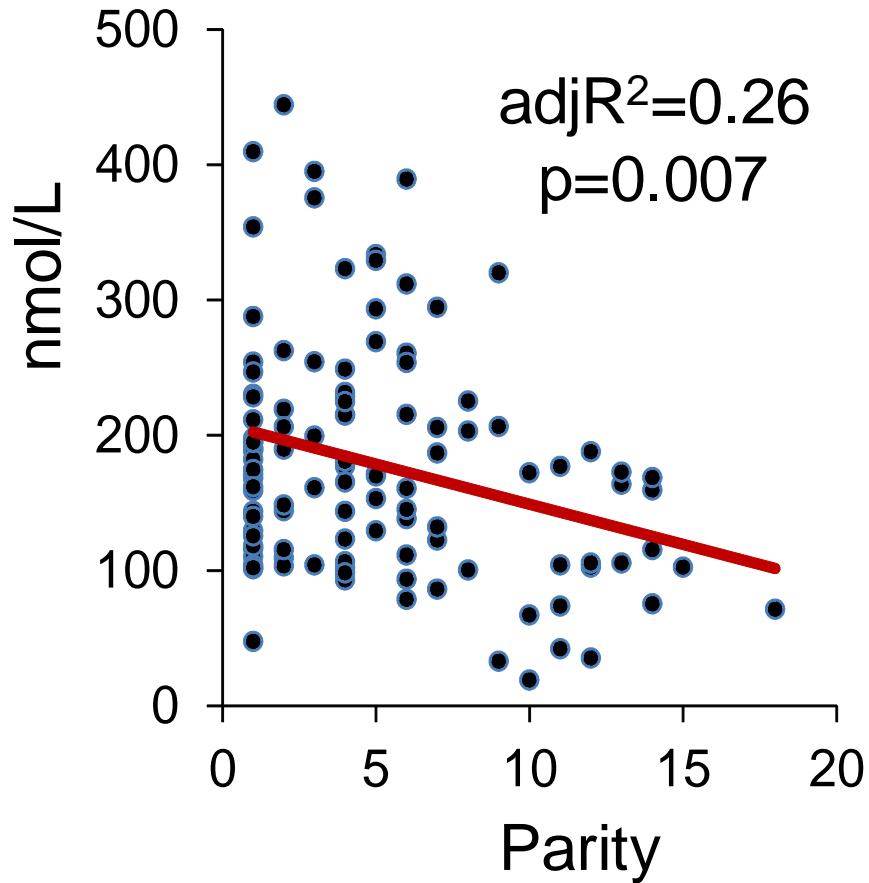


Sex differences in glucocorticoid receptor density in the intestinal epithelium or neural regions of interest during infancy?

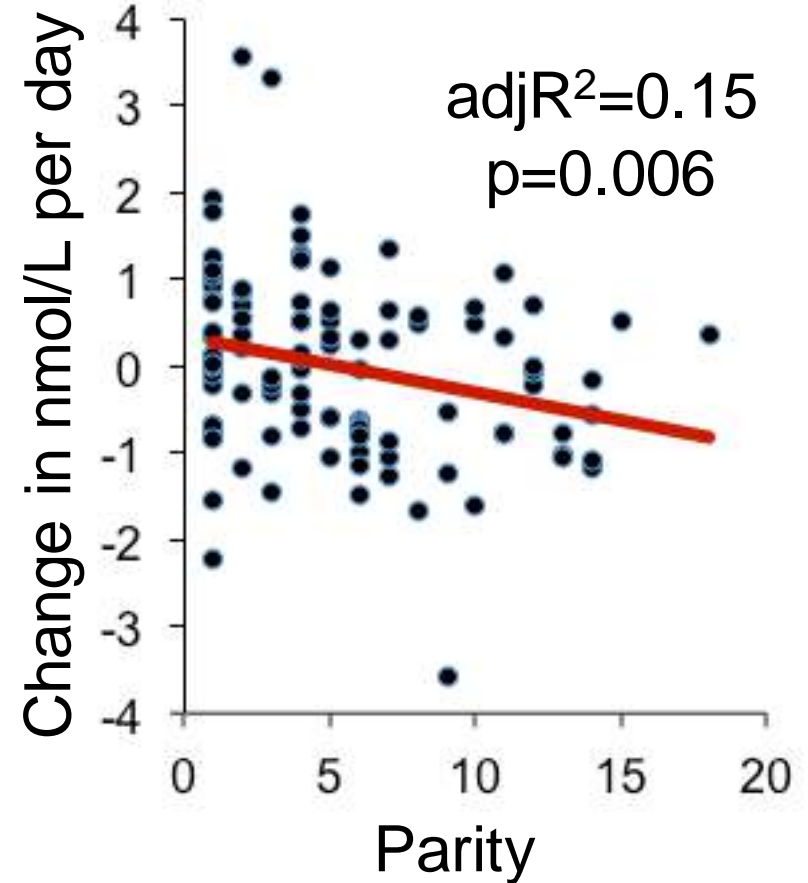
What maternal characteristics predict cortisol concentrations in milk?

Lower Parity Mothers:

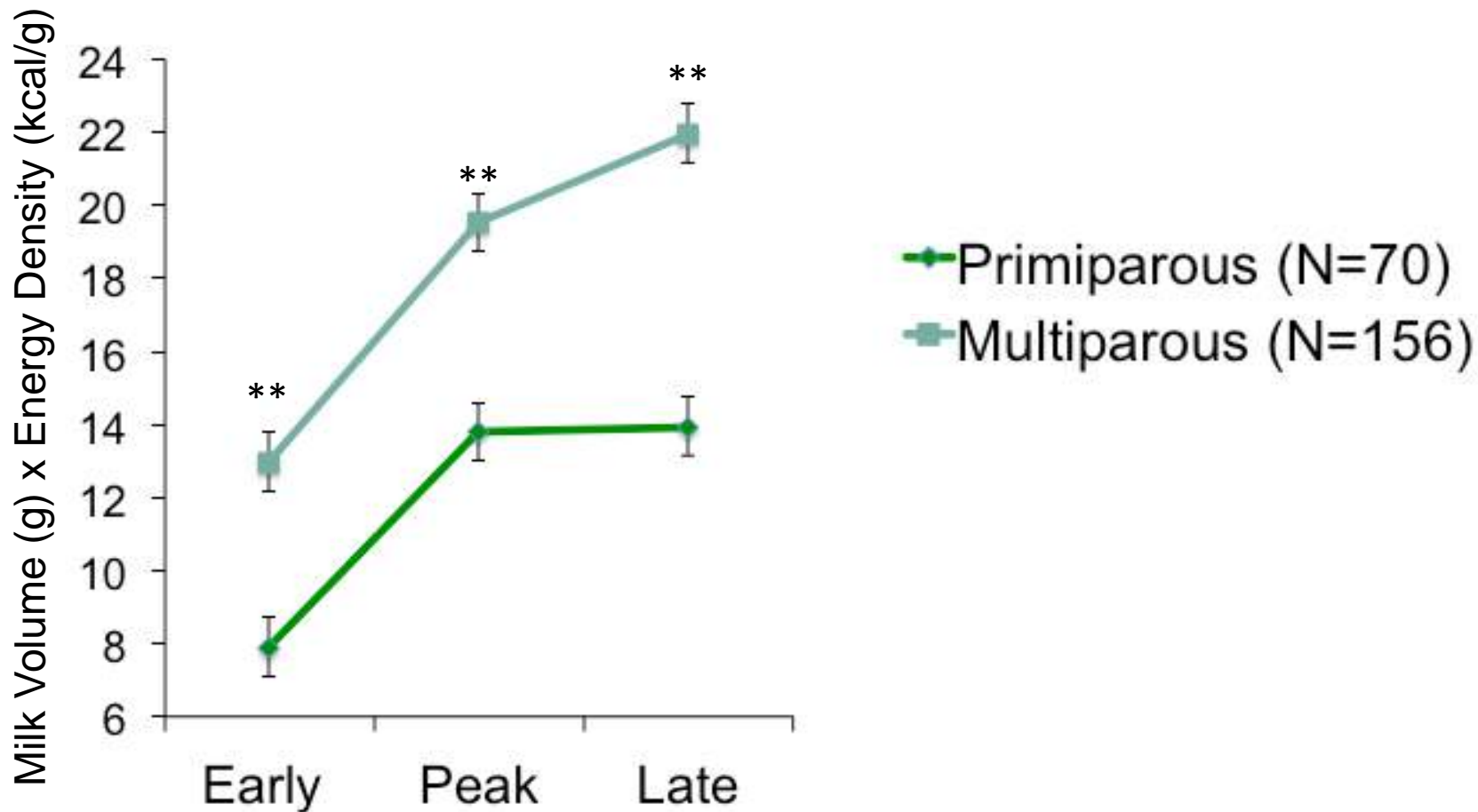
Higher Milk CORT



Increase CORT across Lactation



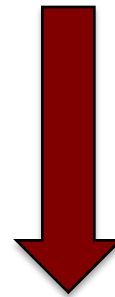
Handicapped Milk Production & Increased GCs in Milk



Are Milk Hormones Developmental Instructions?



More Nervous &
Less Confident
Temperament

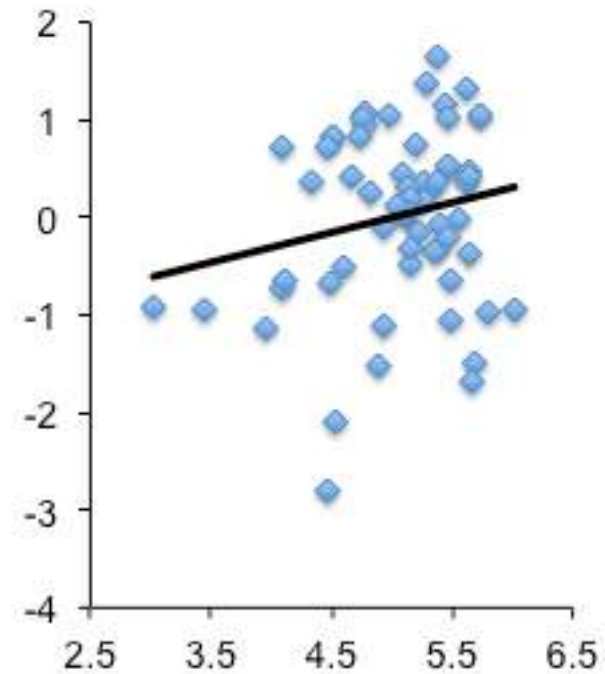


Prioritize Growth?
Cognitive Development?

Milk Cortisol Associated w/ Growth



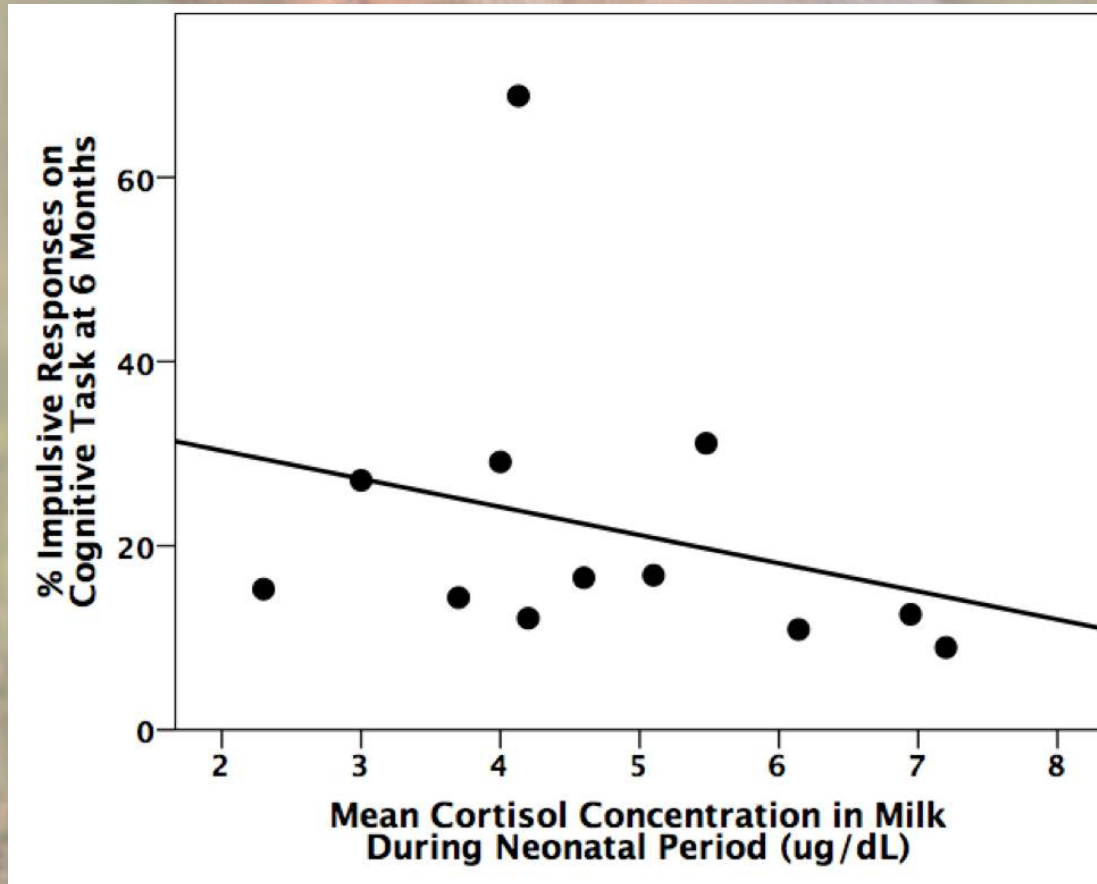
Infant Growth Rate
(residualized values)



Increase in Cortisol
across Lactation (ln)



Higher Milk Cortisol → Better Cognitive Performance



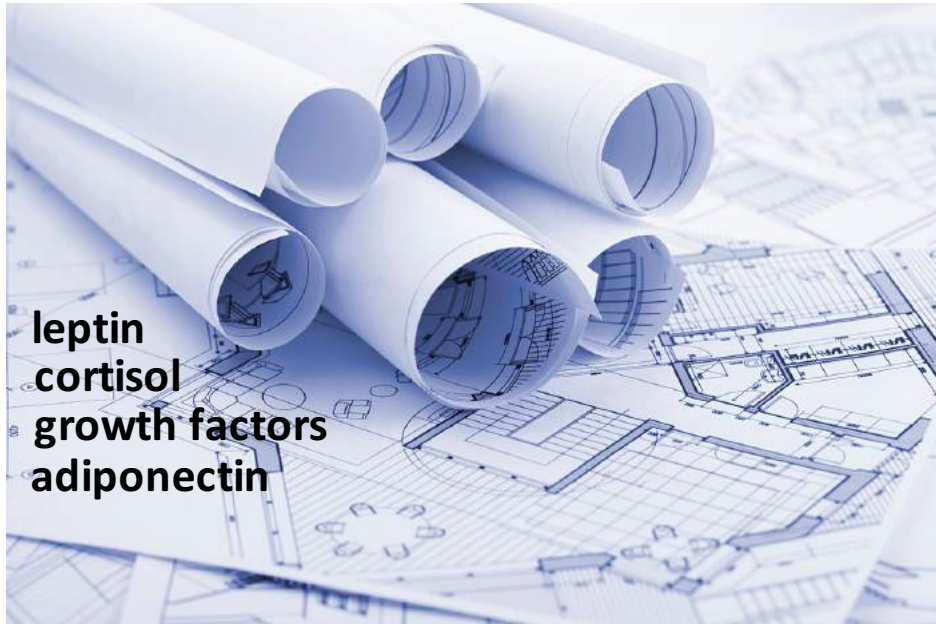
Dr. Amanda Dettmer



Dr. Steve Suomi

Milk nutrients are the
BUILDING BLOCKS

Milk hormones are the
BLUEPRINTS



leptin
cortisol
growth factors
adiponectin

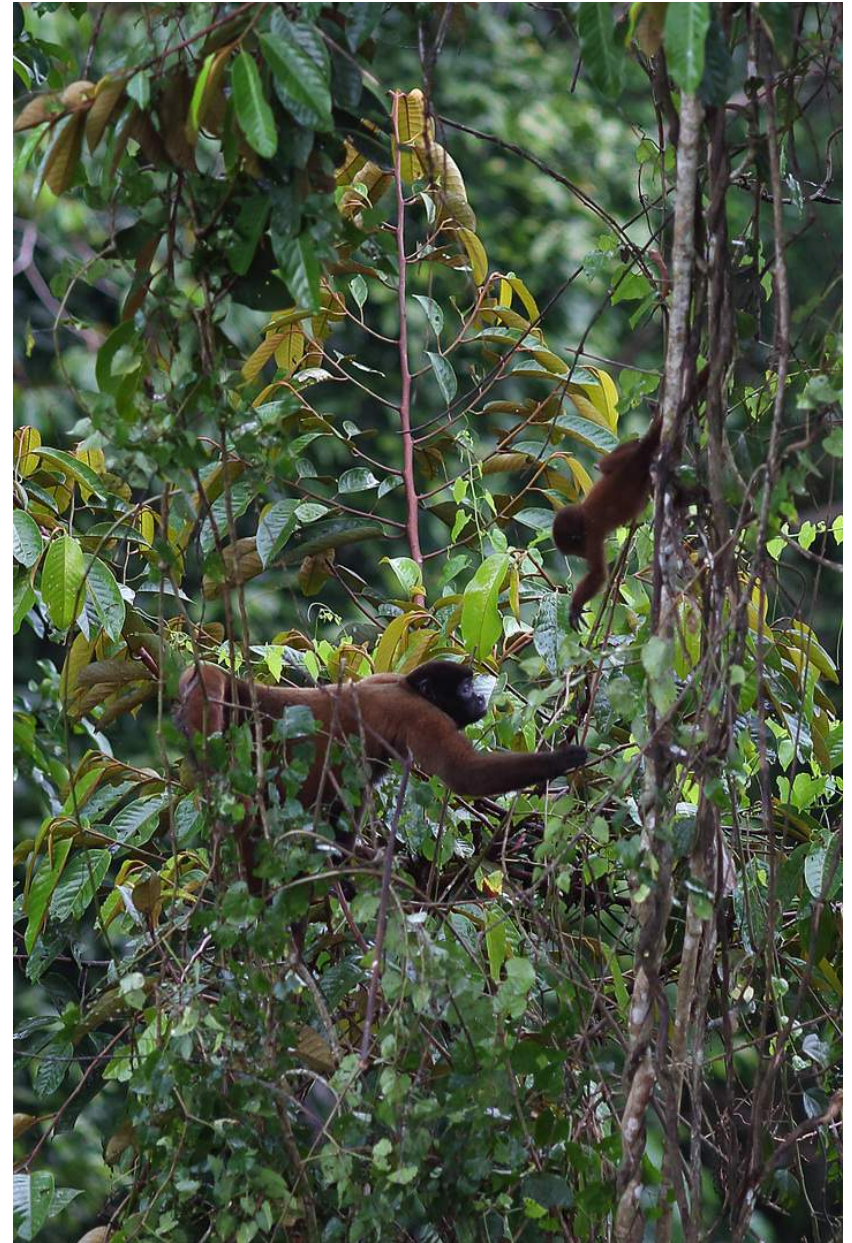
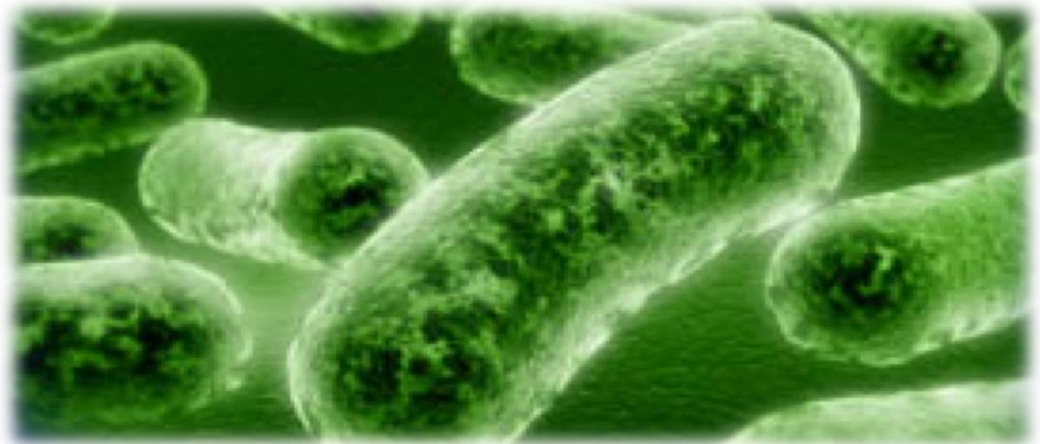
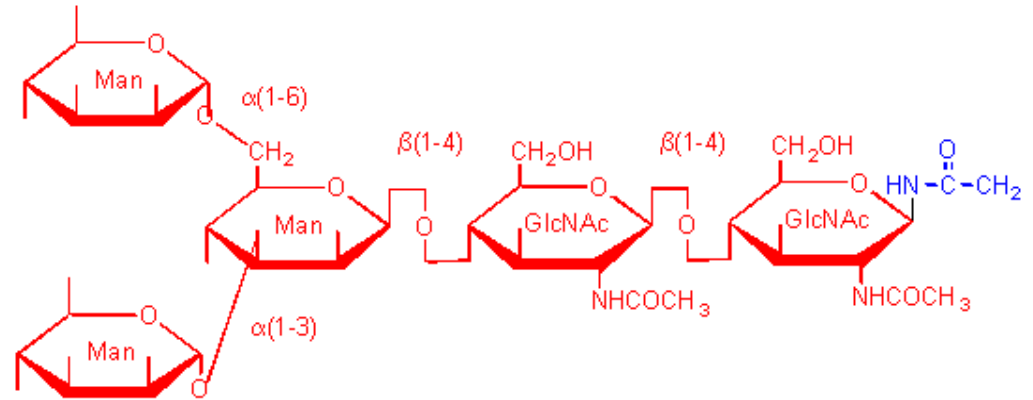


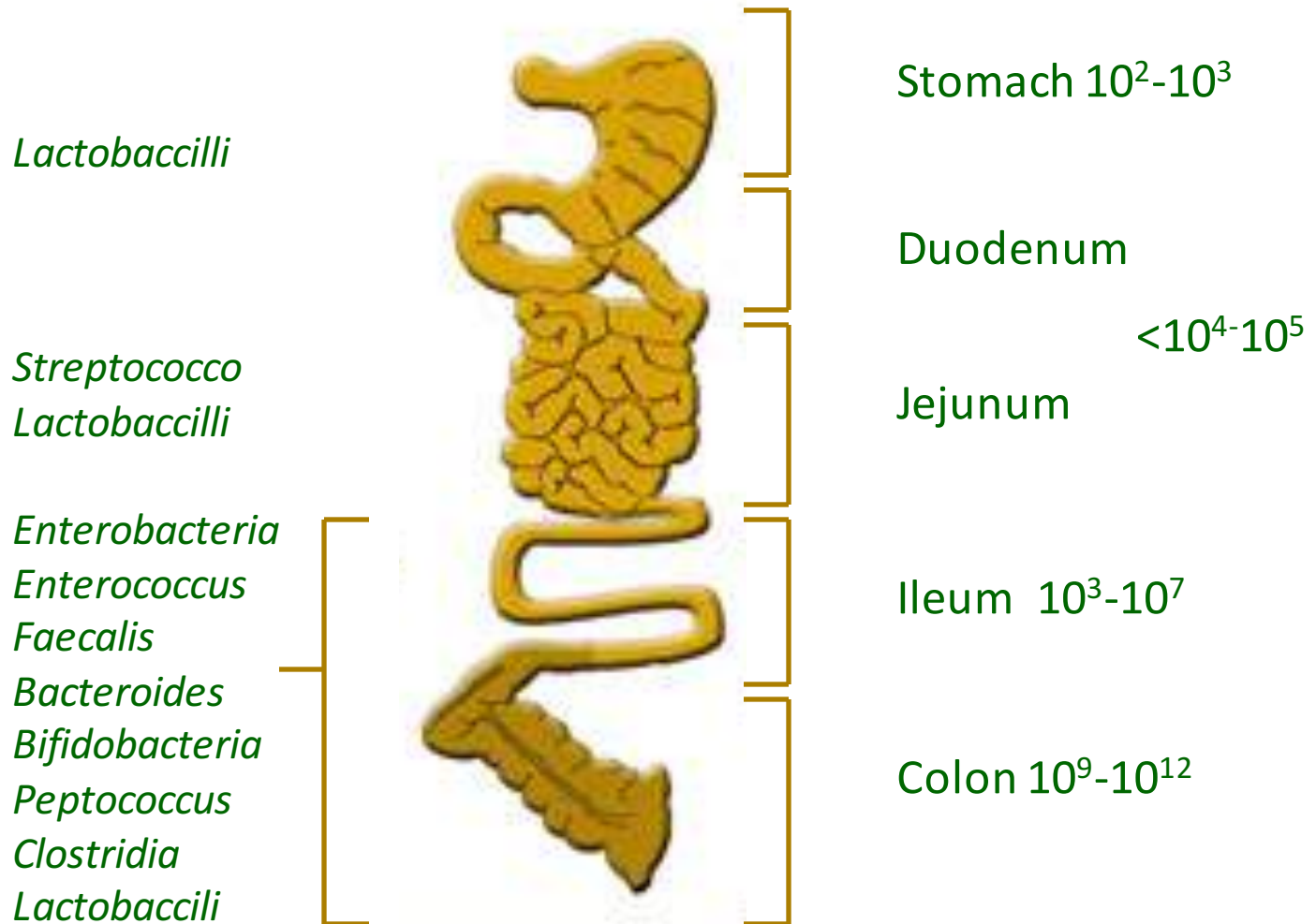
Photo by Kathy West

Mother's milk does not only feed the infant...



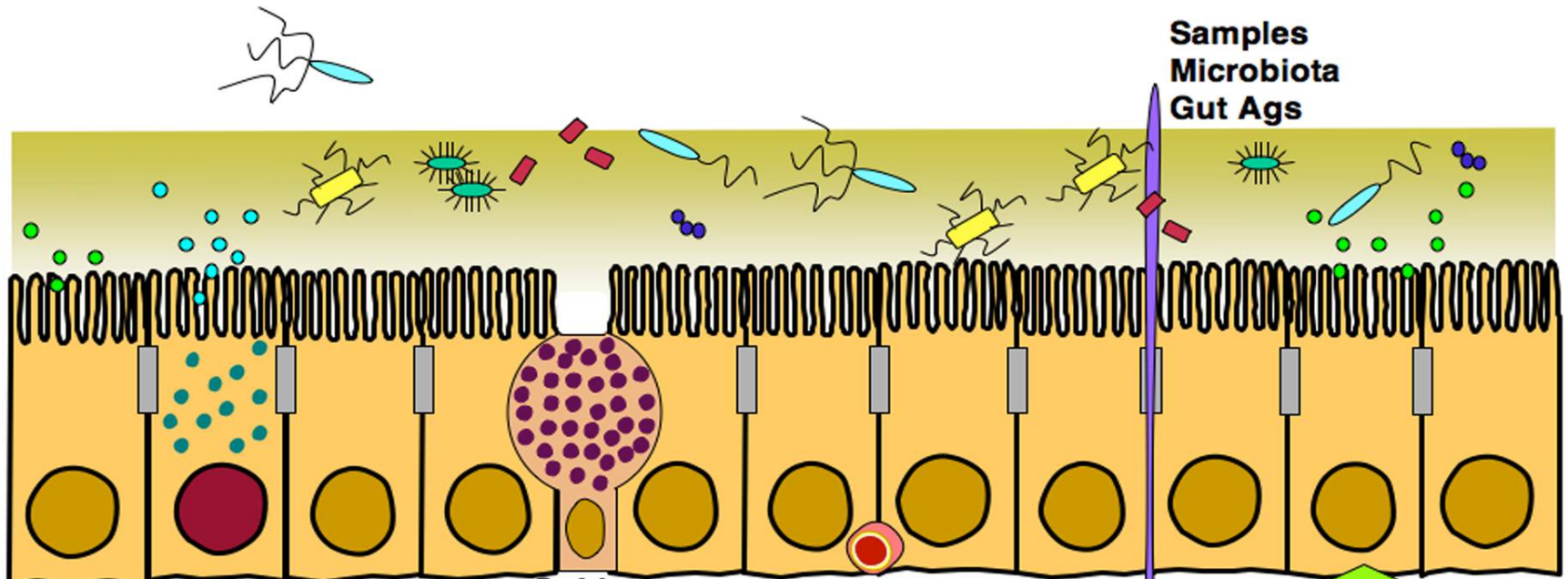
Intestinal Microbiome

>100 trillion* micro-organisms, > 500 species





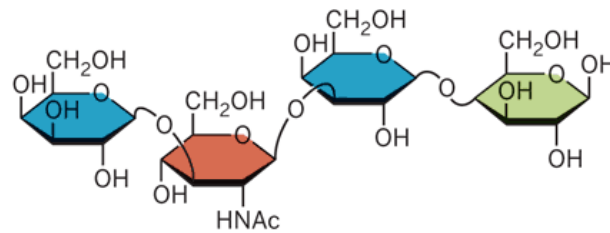
Gut Epithelium & Commensal Bacteria



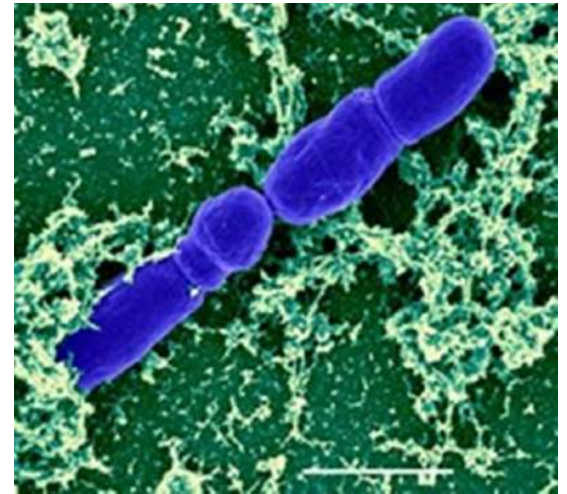
Microbial Communities Established in Infancy



Human Milk
Oligosaccharides

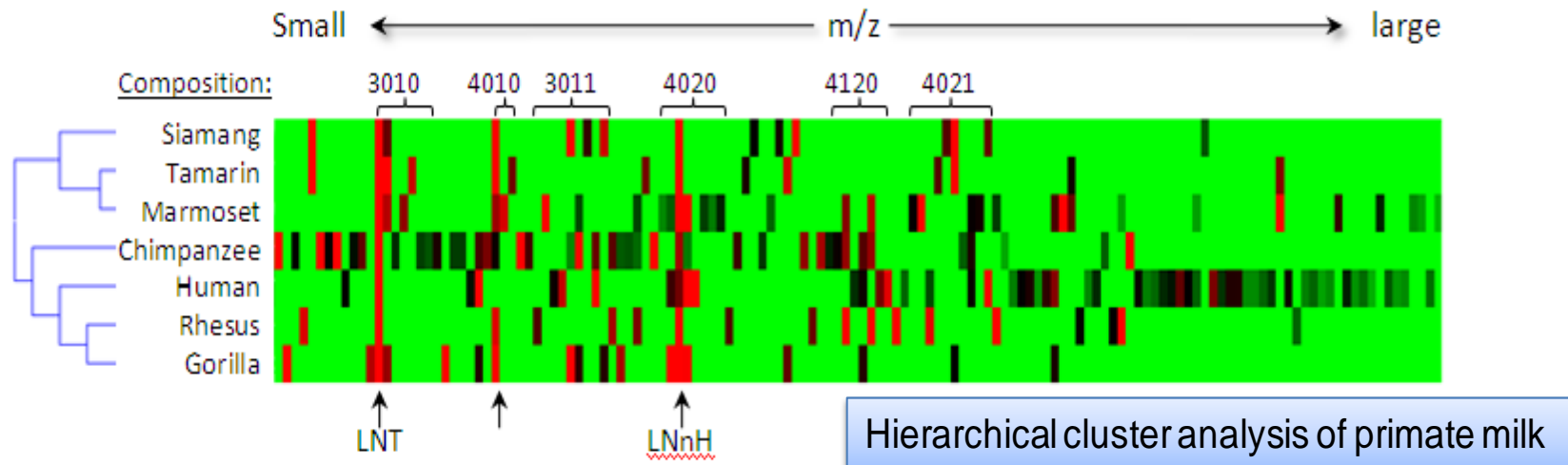


lacto-N-tetraose

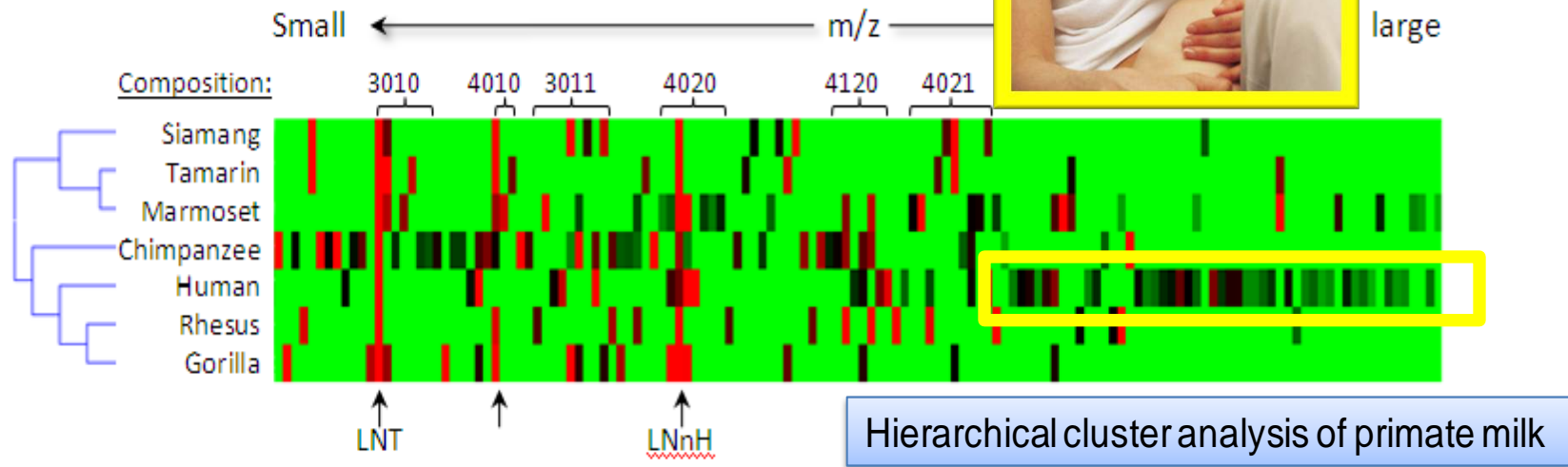


Bifidobacterium infantis

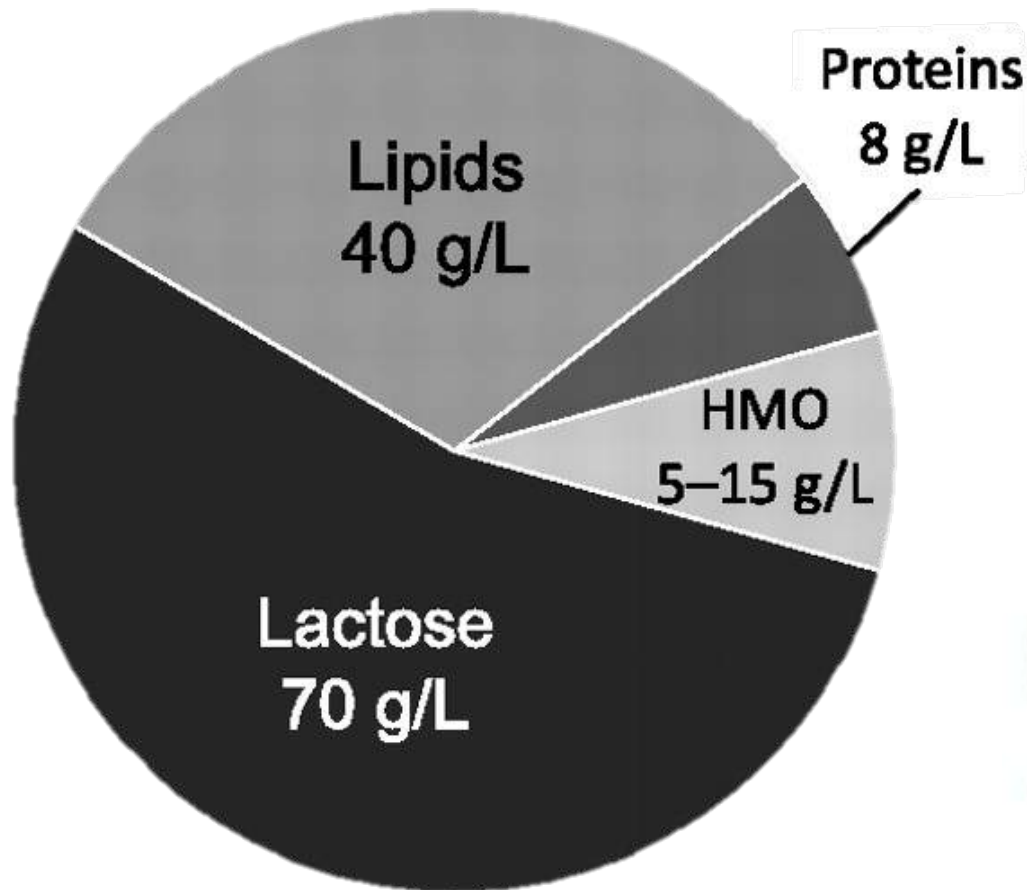
Quantitative Comparison of Oligosaccharides among Primates



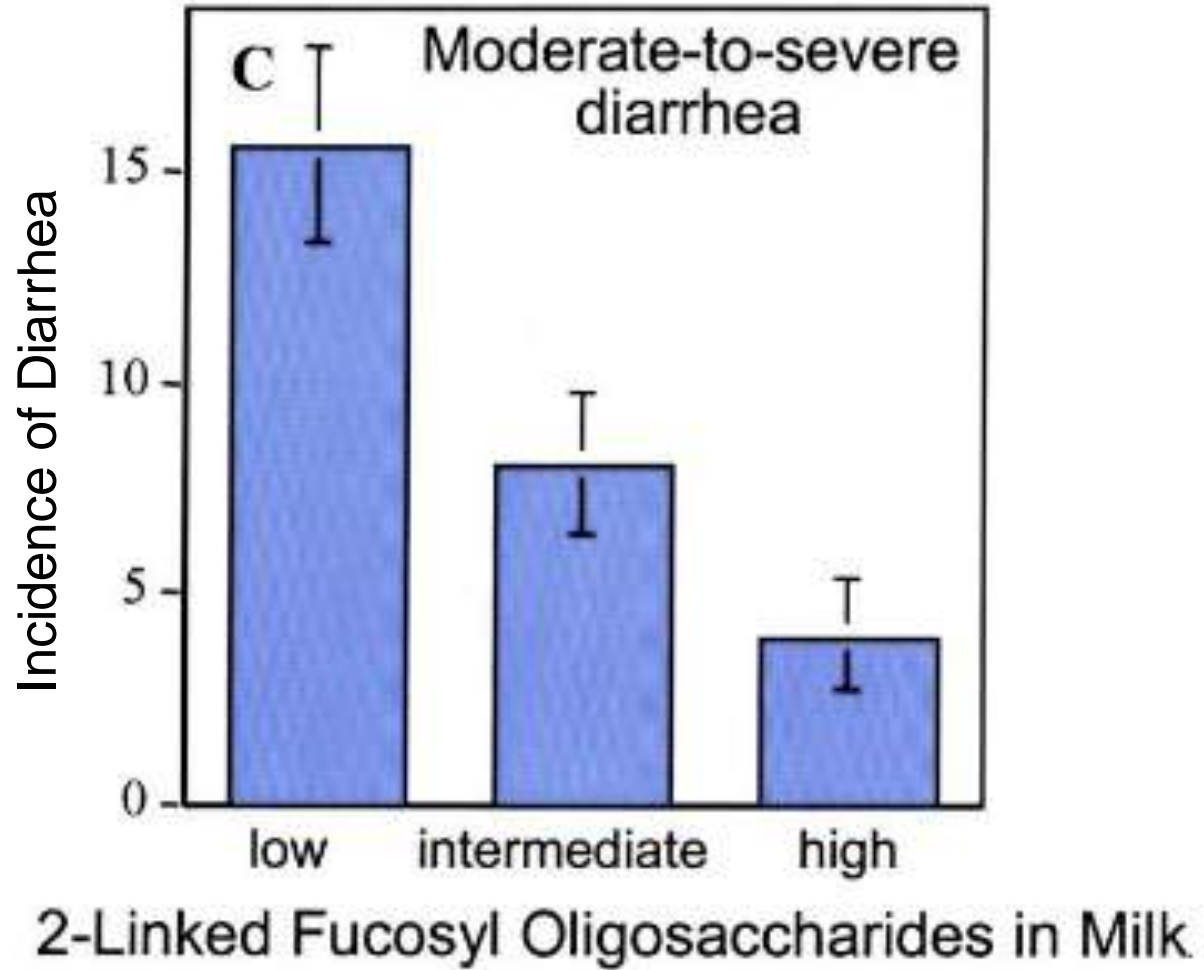
Quantitative Comparison of Oligosaccharides among

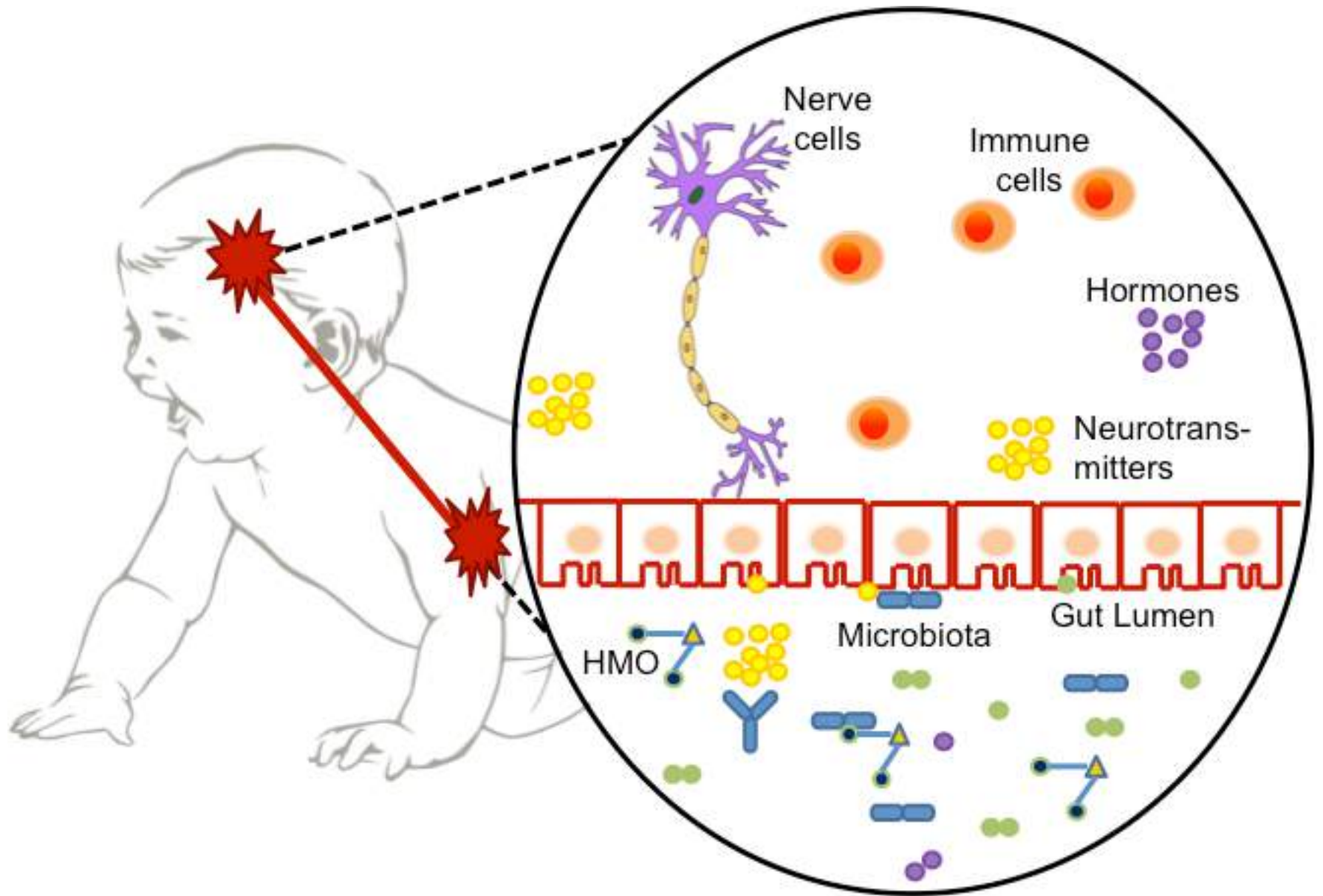


Human Milk Oligosaccharides (HMO)

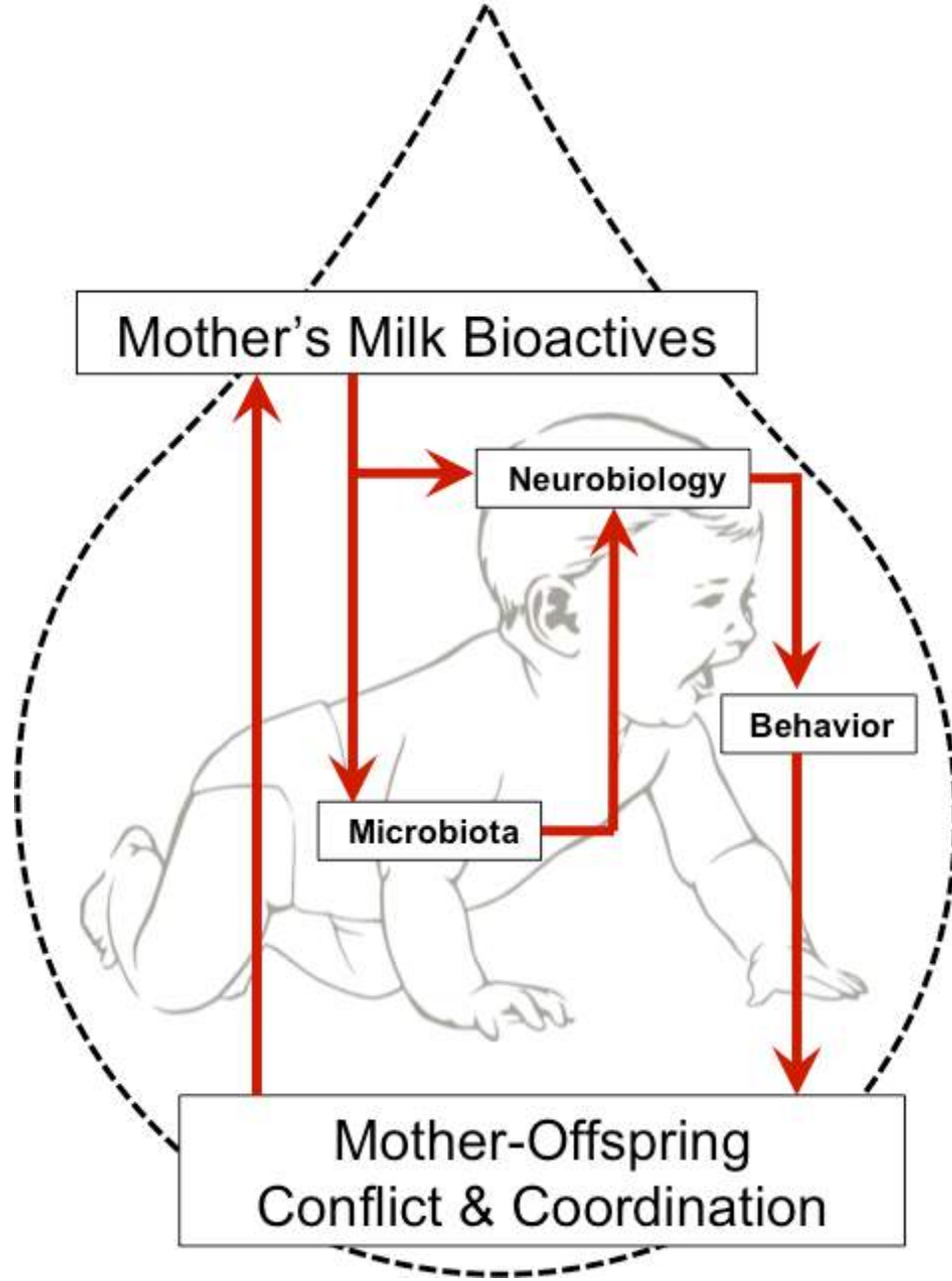


reviewed in Zivkovic *et al* 2011, *PNAS*





Allen-Blevins, Sela, & Hinde 2015 EMPH

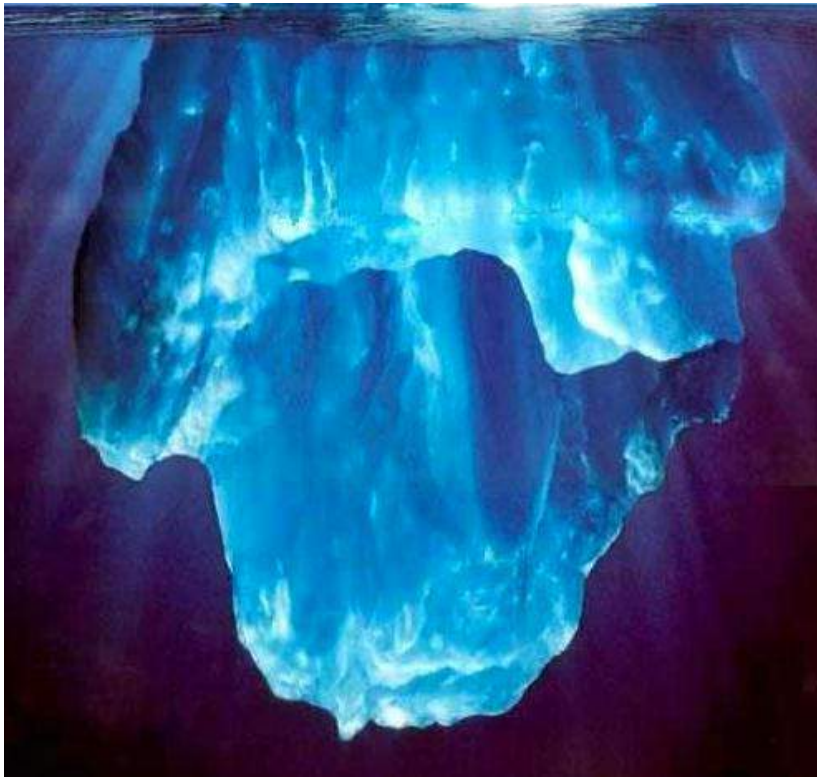


Allen-Blevins, Sela, & Hinde, 2015, EMPH

MOTHER'S MILK



What We
Know



What We
Need to
Find Out



Acknowledgements



Dr. Amy Skibiel
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Laura del Rosso
Laura Colander
Brett Farnham
Dale Sussdorf
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Kathy West



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