Genomic Revolution: The Next 10 Years
A vision for the future:
how will the dairy business look like in 2029?
The Past. Looking back to KY in 1950’s

1. Nature. April 25, 1953 (Structure of DNA)

2. Born February 1954
   Pictured at 10 yr. of age
   8y 1m: 16,990M 626F

3. DeLaval Milker
USA findings: Dairy feeds most people from USA land base


World view: Growth of population will be in Africa and Asia

1. 10.4 Billion People
2. 93% of growth will be in Asia and Africa, 82% in Africa alone
3. Export Markets

Estimated Global Milk Consumption in 2017 and 2067, kg

- **2017 @ FAO, 87 kg**: 652,524,057,600 kg (100%)
- **2067 @ FAO, 119 kg**: 1,249,500,000,000 kg (191%)
- **2067 @ EAT-Lancet, 91 kg**: 958,125,000,000 kg (147%)
World view: How many dairy cows to meet demand

Dairy Cows Needed in 2067 with Different Milk Yield Averages

- 1.25% increase/yr: 249,500,799
- 2X of 2017 Average: 262,657,953
- 2017 Average: 525,315,906

Average Yield Per Cow in 2067
World view: **26 countries have 75% of dairy cows in world today**

FAO estimates 274 million total dairy cows in 2017

- **4,200 to 10,500 kg** => 36,012,576 cows
- **1,900 to 3,200 kg** => 45,762,100 cows
- **500 to 1,700 kg** => 79,918,619 cows
- **200 to 500 kg** => 44,290,009 cows

FAOSTAT 2017
World view: **20 countries produce 75% of cow’s milk**
Current view: Cow’s milk is mostly consumed in non-fluid forms in the USA.

- **1.**
  - **Milk vs Other dairy**
  - 23% vs 77%
  - 56 billion lbs.
  - 159 billion lbs.

- **2.**
  - **Caseins and other proteins:** A1, A2, better cheese yields, etc.
  - **Fatty acids:** Beneficial to health
  - **SCC:** 200,00 or lower
  - **Processing:** Best for ultrafiltration, UHT, aseptic packaging
  - **New Products:** USA seems to be lagging
USA milk supply: Milk supply growth exceeds population growth.

USDA estimated components of USA milk supply on a milk fat basis are 3.7% fat solids, 8.8% skim solids.
USA markets: *Balancing volume and components with % instead of pounds*

Change in Pounds of Milk and Components
Marketed with 4.2% F and 3.2% P

*Calculations by Jack Britt, January 2019*

-11.700 ~156,700 semi tanker loads of milk

-12.00  -10.00  -8.00  -6.00  -4.00  -2.00  0.00  2.00

Billion Pounds

-1.00

-0.568

-0.246

0.323

Milk

Fat

Prot

Lact

1

2
View ahead: Milk prices in USA will continue to be VOLATILE!

Inflation Adjusted Mailbox Prices USA

60% below

40% above

70% Difference

Original data: Hoard’s Dairyman April 25, 2018, page 264.
Future: **Shareholders and politicians focus on short-term results**
Future: Population, land for food production and climate change.

1. 82% of people
2. 81% of food
3. N. hemisphere

Longer growing season

Equator

Arable Land per Person (acres)

< 0.5 acres/person

>0.75 acres/person
Future: Adapting to climate change on dairy farms

Temperature change from 1971-1999 average (°F)

1. Cooling Cows
2. Efficient Irrigation
3. Healthy Roots

USA future climate examples:

1. Edmonton AB will feel like St. Cloud MN
2. Fresno CA will feel like Tijuana MX
3. Gainesville, FL will feel like Ciudad Victoria MX
4. Dalhart TX will feel like Presido TX
5. Quebec City, QC will feel like Southgate MI
6. Plattsburgh NY will feel like Noblesville IN

[Links to demonstration: https://fitzlab.shinyapps.io/cityapp/]
Looking ahead: Understanding the dairy herd as a SUPERORGANISM

We cannot learn about herds by studying these:

1. Gene
2. Cell
3. Organ
4. Animal
13 production units (herds)

• Study practices, trends, long-term
• Use sensors, surveys, samples
• Assess micro- and macro-environments
• What characterizes “good management”? 
• Do herds behave as superorganisms?
Sensors, automation, robotics, artificial intelligence

- Soils
- Crops
- Silo/bales
- Lagoon
- Natural areas
- Barns
- Milking center
- Personnel
- Equipment
- Commodities
- Robots
- Air
- Waterways
- Roads
- Vehicles

Data in the cloud & Blockchain

Integrated sensors

Reliable
Repeatable
Precision-Accuracy
Less labor
Disruptive: Open source research and dissemination (Why do we need journals when our base is declining?)

- Dairy Farmers
- Cloud Computing
- Blockchain
- USDA ARS Scientists
- Data Centers
- Parlor Sensors
- On-cow Sensors
- Dairy Research Ctrs.
- Dairy Scientists
- Dairy Processors

200,000 trillion calculations per second
Looking ahead. **Genetics of cows of the future**

- Efficient, smaller environmental footprint
- Gene based, not breed based
- Healthier
- Proprietary genes licensed in embryos
- Gene editing to move genes within & among breeds
- Includes their microbiome

1. Lines of X-bred
2.
Genetics of the future: Four global dairy cattle lines

Genetics of the future: **Focus shifts to understanding “epigenetics”**

Environmental Action | weeks, months, years | Observed Response
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Incidence, metritis | Genetic | Epigenetic (broadly defined)
Incidence, ketosis
Incidence, RP
Days to 1st AI
First calving interval
Incidence, mastitis
SCC average
Persistency of yield
Productive life
Lifetime protein
Age first calving
Lifetime fat
Lifetime milk
Days to 1st CL
Energy balance
Net income
BCS
Dry matter intake
ME protein
ME
ME milk
Lactose%
Protein%
Fat%

Retrospective analyses of Big Data and temporal relationships (RNAs, Methylation, Histone Acetylation)

19% | 81%

Bennet Cassell, Using Heritability for Genetic Improvement

[https://pubs.ext.vt.edu/404/404-084/404-084.html](https://pubs.ext.vt.edu/404/404-084/404-084.html)
Sensors and robotics: Artificial Intelligence in dairy management
Mechanisms: How does weight loss affect fertility of a cow’s eggs?

"Britt Hypothesis" Here's what observed.

Here's a diagram of our hypothesis.

Primordial pool
Activated oocyte from ovarian reserve

Microscopic size

Weight loss Environment

Ultrasound size

Ovulation of egg

Days Before or After Calving

101 Days

1

Maintained = 62% CR

Lost = 25% CR

The Britt Hypothesis: 22 years later...

Carvalho et al, J Dairy Science 97:3666-3683, 2014

Pregnancy Rates (%) to Timed AI in Holstein cows

- Lost: 25% (789 cows)
- Maintained: 38% (675 cows)
- Gained: 84% (423 cows)
Future: Do cows have to lose weight to have high yields?

Future: Will some bulls produce daughters that are more robust?

Resilience: Example of genetic resilience through variation in a trait.
Creating line: *Breeding in the petri dish*

1. **Fertilized Oocytes**
   - Culture & scan genome of ICM cell

2. **Bovine Blastocyst**
   - Harvest and culture Inner Cell Mass cells with growth factors

3. **Stem Cells**
   - Culture stem cells with special growth modifiers

4. **Oogonia & Spermatogonia**
   - Culture oogonia and spermatogonia with meiotic factors

5. **“Oocytes” & “Spermatozoa”**
   - IVM & IVF

6. One Generation Per Month

7. 3-D Printing? Wow!

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Source: [https://www.the-scientist.com/?articles.view/articleNo/47256/title/From-Stem-Cell-to-Oocyte-In-a-Dish/](https://www.the-scientist.com/?articles.view/articleNo/47256/title/From-Stem-Cell-to-Oocyte-In-a-Dish/)
Males only fed high sugar for short period
Males mated with normal-fed females
Reprogramming of embryonic genome
Male offspring have increased obesity:


Managing epigenome: *Feed bulls differently in the future to affect progeny?*

Many epigenetic strategies:
- Precise Nutrition
- DNA Regulators
- Environmental Control
- Stem Cell Transfers
Looking ahead: Managing the microbiome to benefit crops and cows.
Thank You for this Opportunity

Reaching for the Future
Envision It and Create It