Feed-a-Gene

Adaptin
to impr
system
tion

A general method to relate feed intake and body mass across individuals and species

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EAAP
29 August 2019

Motivation

- Main determinant of food intake - animal size

- Mathematical descriptions of the size-intake relationship are useful
  - Characterise intake of individuals, breeds and species
  - Help to estimate associated traits
    - Efficiency of feed utilisation
    - FCR
  - Input to mechanistic models of nutrient requirements

Problem - form of size-cumulative-intake relationship

- Several model curves, since at least Spillman's (1924) law of diminishing returns
- Parsimonious functions chosen by fitting data
  - not based on testable theory
- But, during early growth (=birth to point of maximum growth, i.e. puberty), intake may be misrepresented in many datasets
  - Pre-weaning is excluded
  - Records have constant frequency, while early growth is faster

  => Intake might be less-accurately described by obvious simple functions
- We revisit the evidence - initially, separating early from late growth

Insights from historical data - chickens

Jull, Titus 1928,
"Growth of chickens in relation to feed consumption"

Early growth is curvy
(both experiments)

appears not well fitted by Spillman's model (linear at early growth)

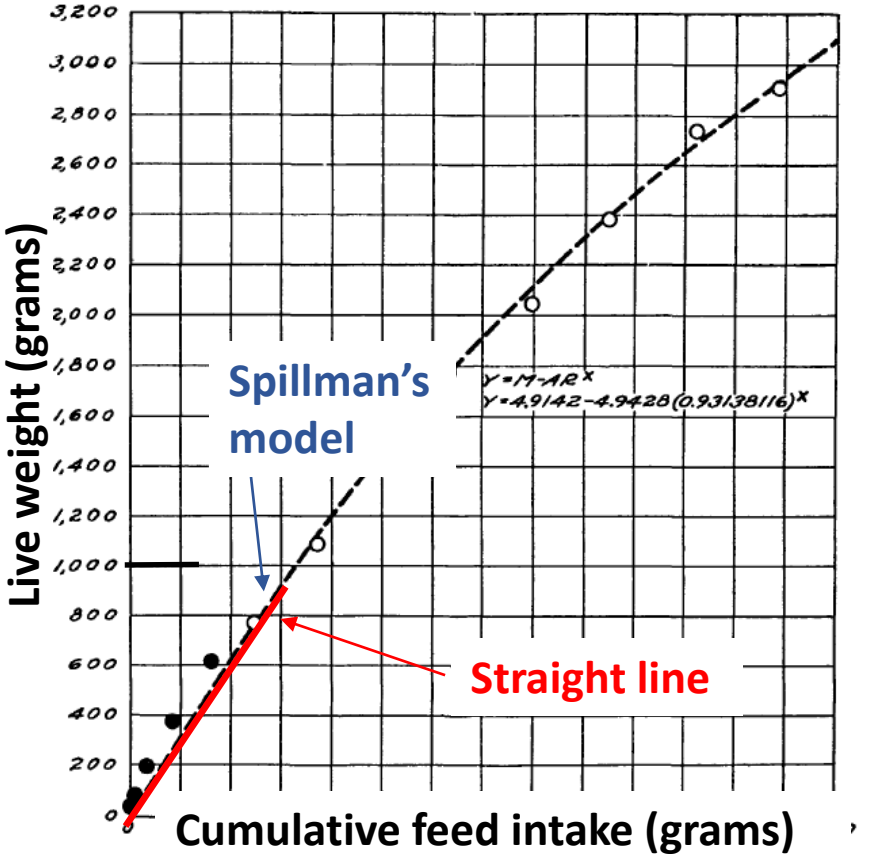

FIG. 4.—Relation between weight of birds in lot 3 (males) and average amount of feed consumed

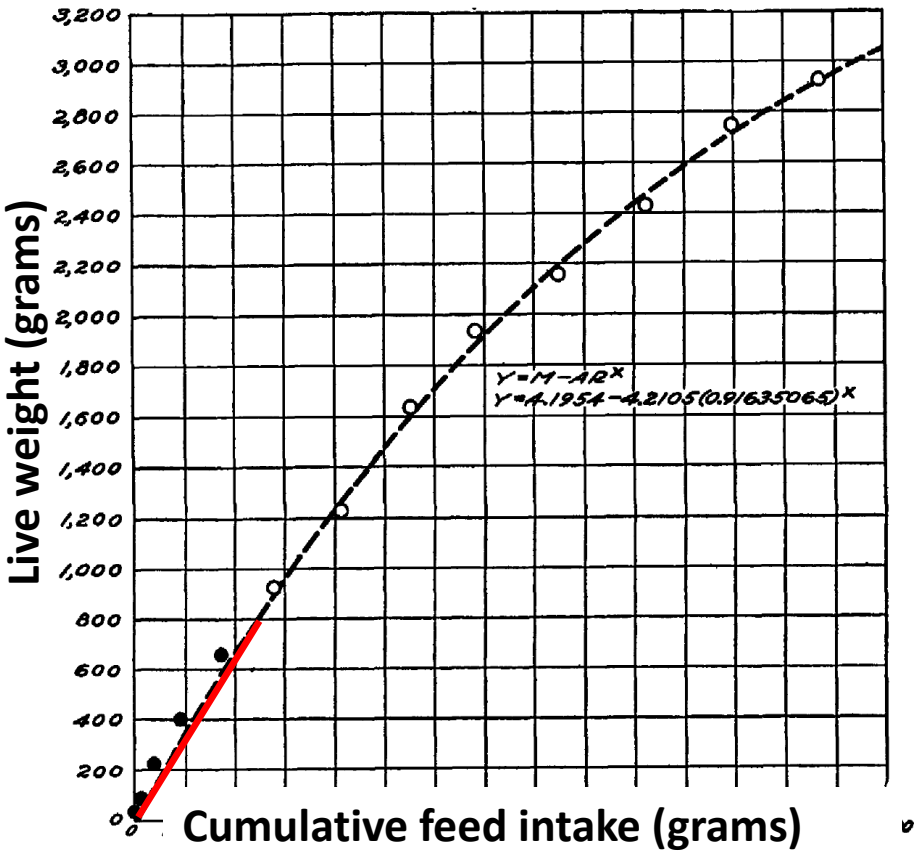

FIG. 5.—Relation between weight of birds in lot 4 (males) and average amount of feed consumed

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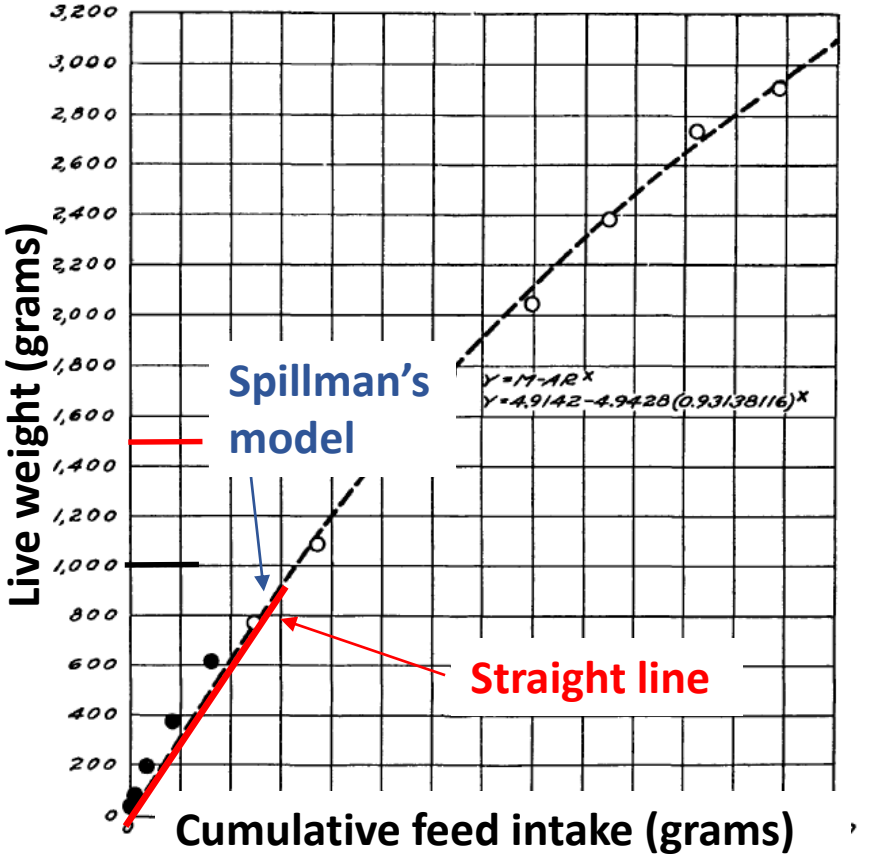

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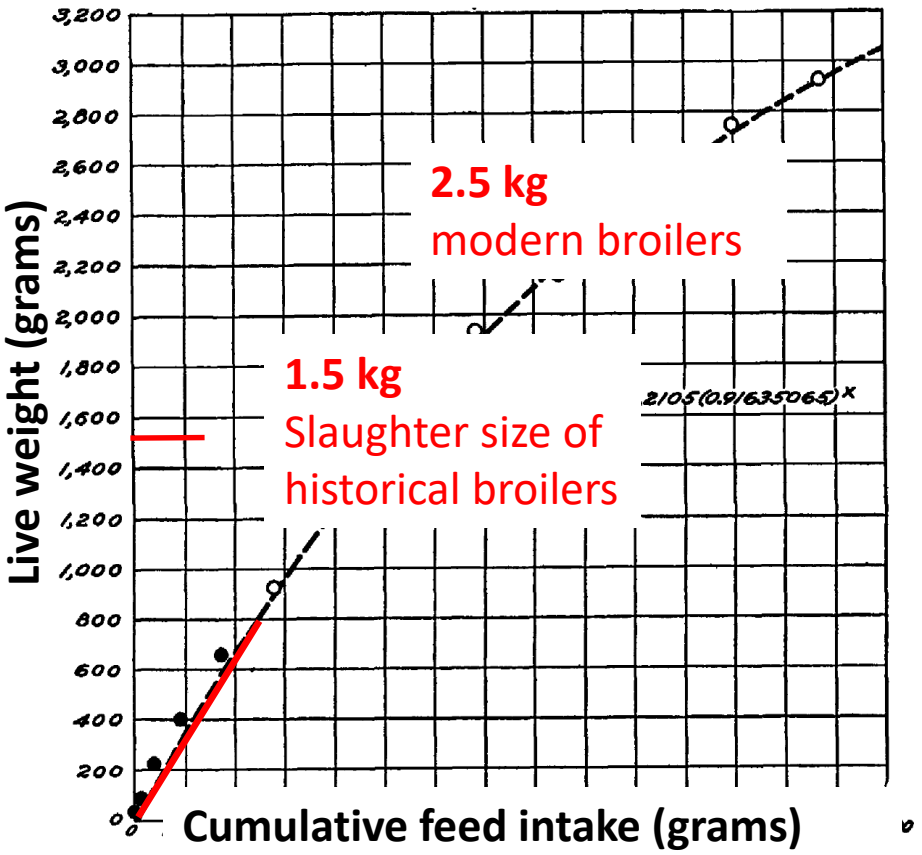


FIG. 5.—Relation between weight of birds in lot 4 (males) and average amount of feed consumed

Insights from historical data - pigs

Shulin-Zeuthen et al 2008,
"A comparison of the Schumacher with other functions for describing growth in pigs"

Pooled individuals.

Early growth better fitted by a curvilinear model than by Spillman's?

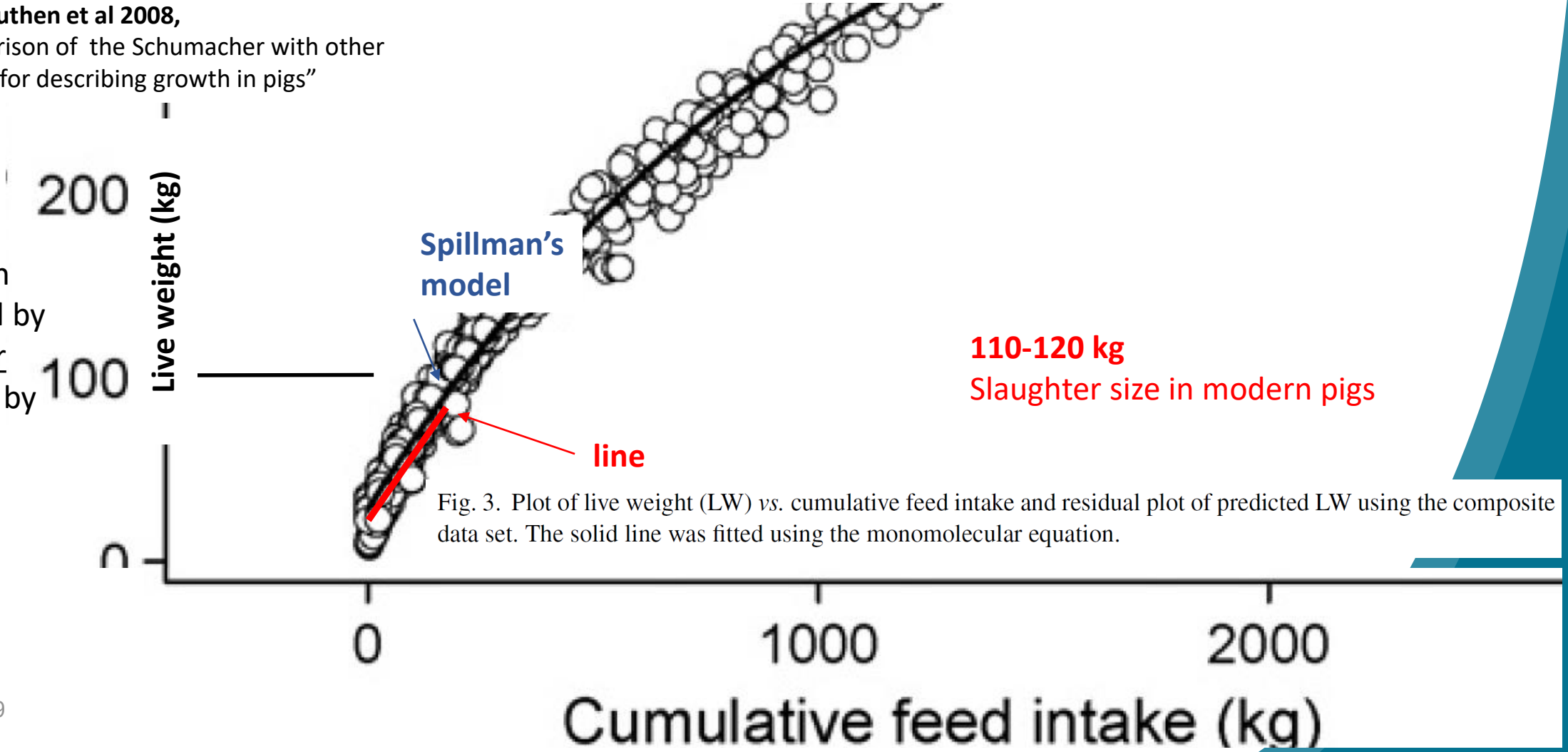


Fig. 3. Plot of live weight (LW) *vs.* cumulative feed intake and residual plot of predicted LW using the composite data set. The solid line was fitted using the monomolecular equation.

110-120 kg
Slaughter size in modern pigs

Evidence from individual data - chickens & pigs

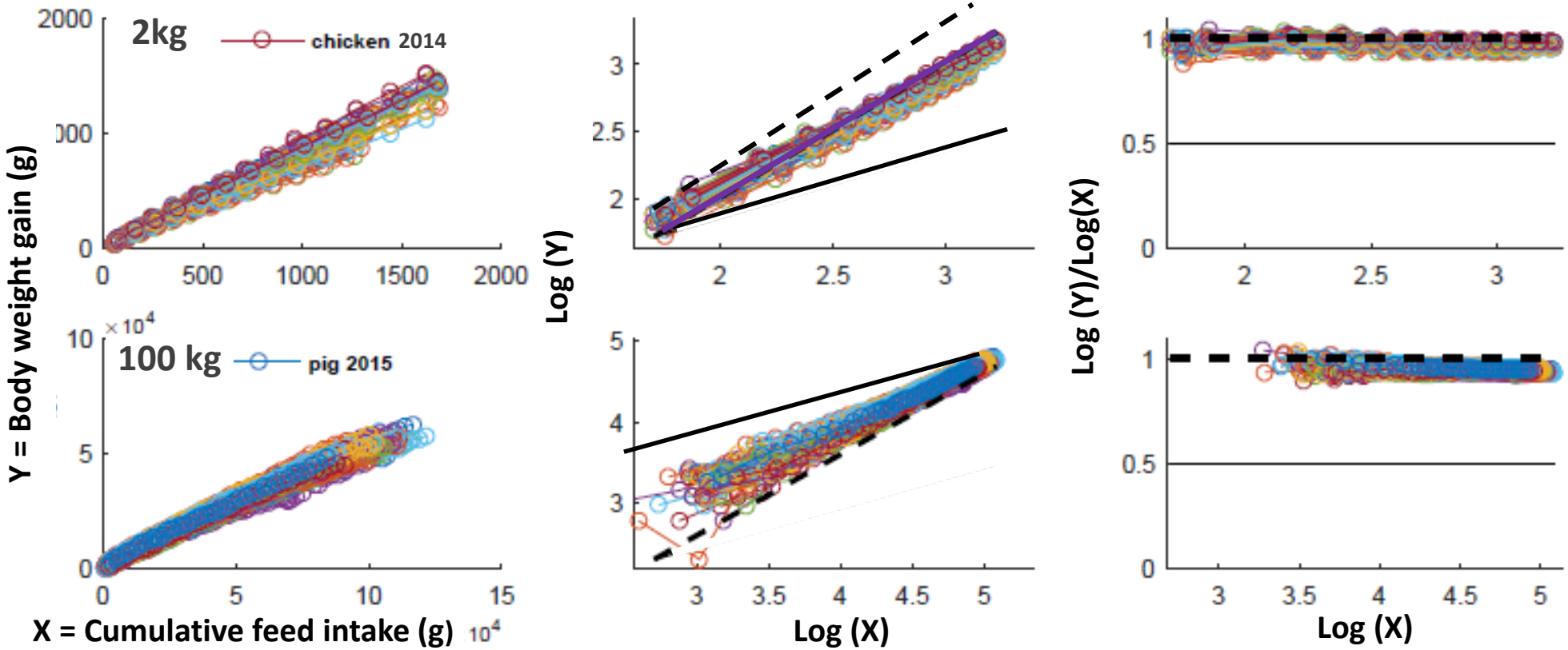
Raw data - modern breeds

log-log transformed

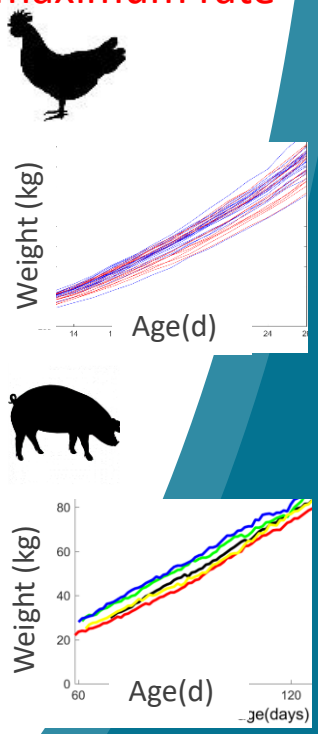
further transformed

n=56

n=50



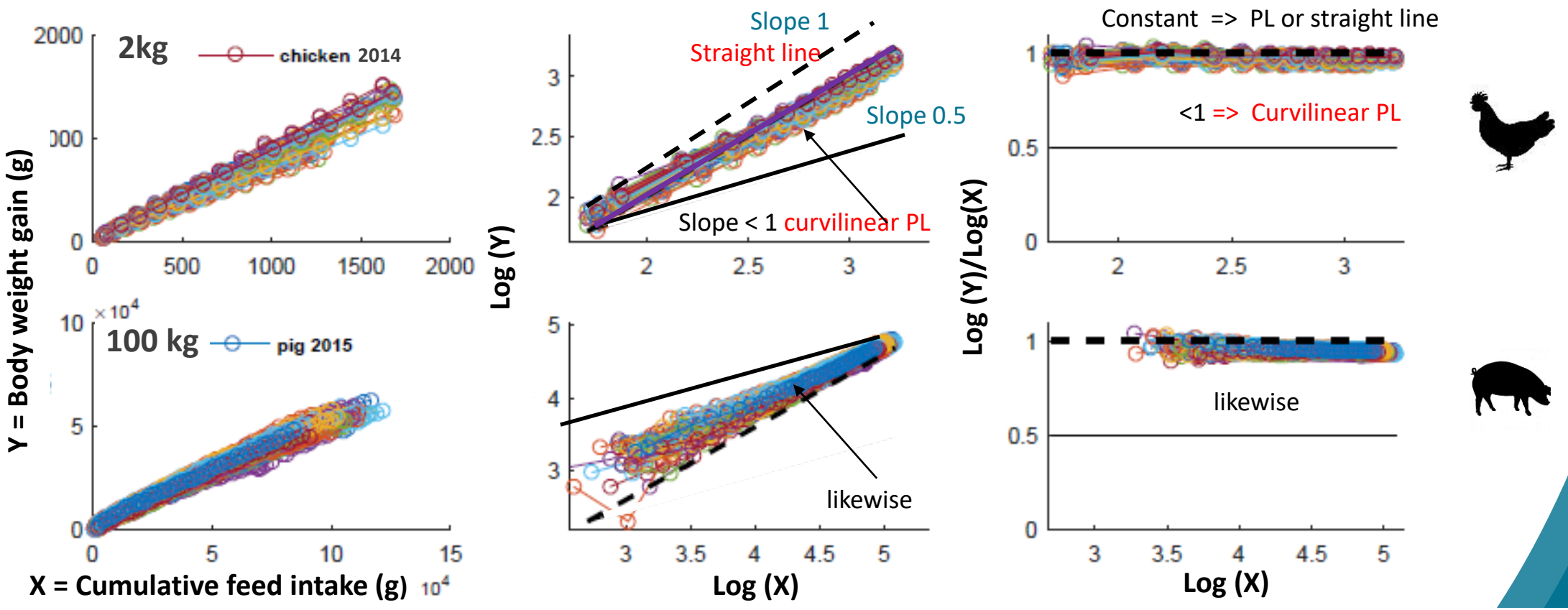
Early growth
Before
maximum rate



Evidence from individual data - chickens & pigs

Raw data - modern breeds | log-log transformed | further transformed

n=56



n=50

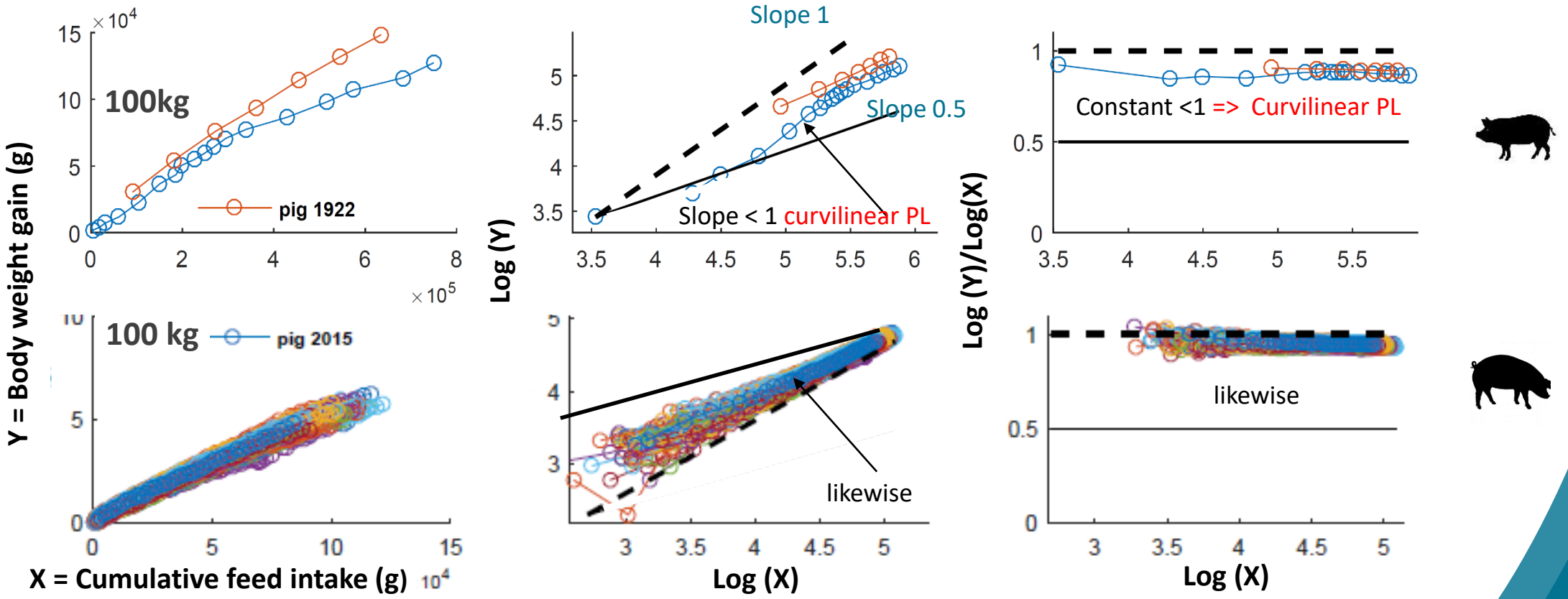
=> allometry (power-law) holds in early growth - across individuals and two species

Evidence from individual data - pigs 2015 & 1922

Raw data - modern & old breeds | log-log transformed | further transformed

n=2

n=50



=> allometry holds in breeds separated by long-term selection

Later growth - mice and rabbits

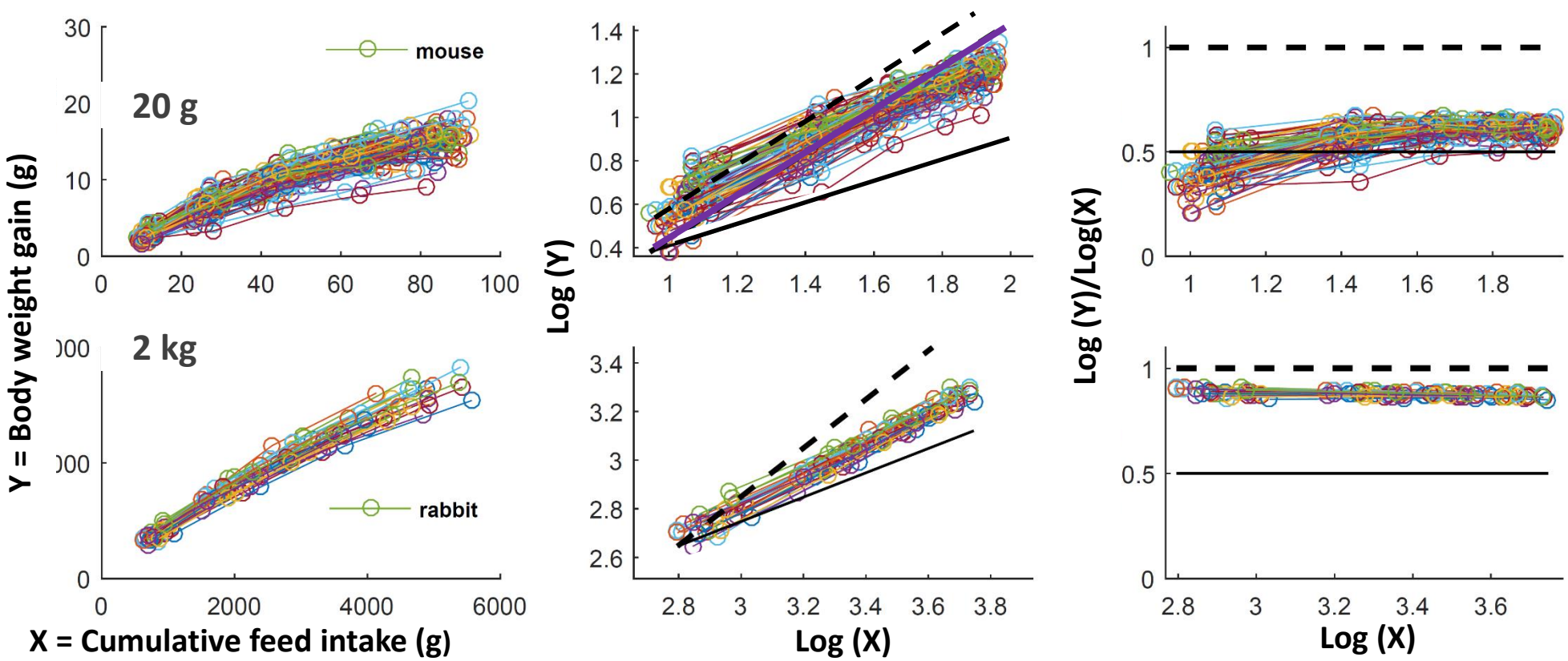
Raw data - modern breeds

log-log transformed

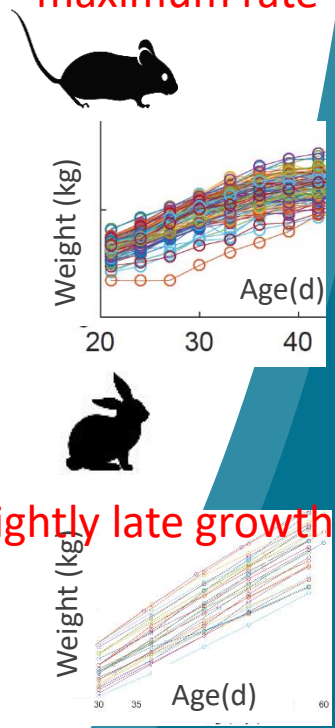
further transformed

n=75

n=26

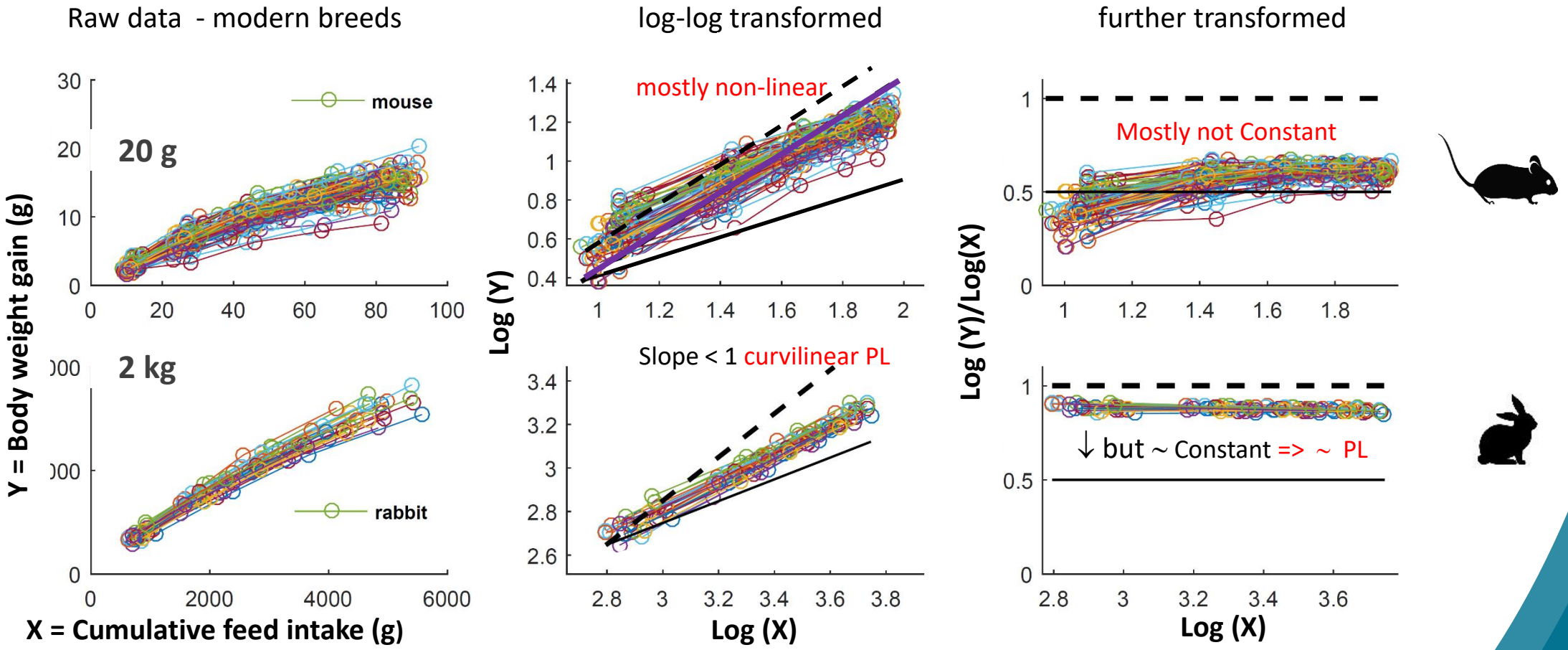


Late growth
After
maximum rate



Slightly late growth

Later growth - mice and rabbits



=> towards maturity, relationship changes gradually from allometric to asymptotic

Hypothesis

CFI = cumulative feed intake (from t_0 to t)
BWG = body weight gain = BW(t) – BW(t_0)

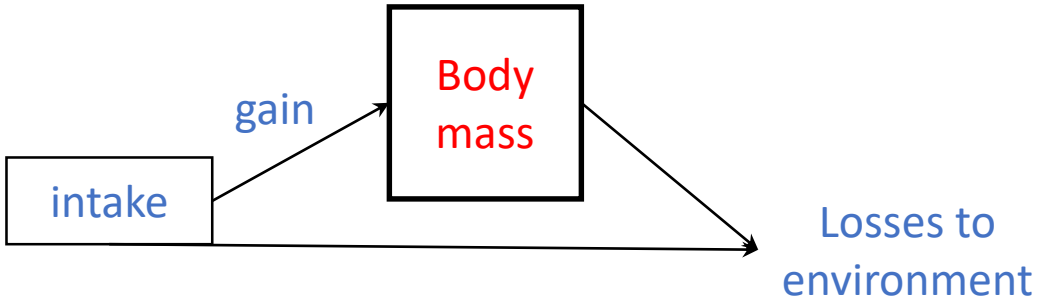
- The traits CFI and BW gain are related by allometry (power-law)

  $BWG = A\ CFI^{b}$ A, b parameters

  during any time period <u>within early growth</u>

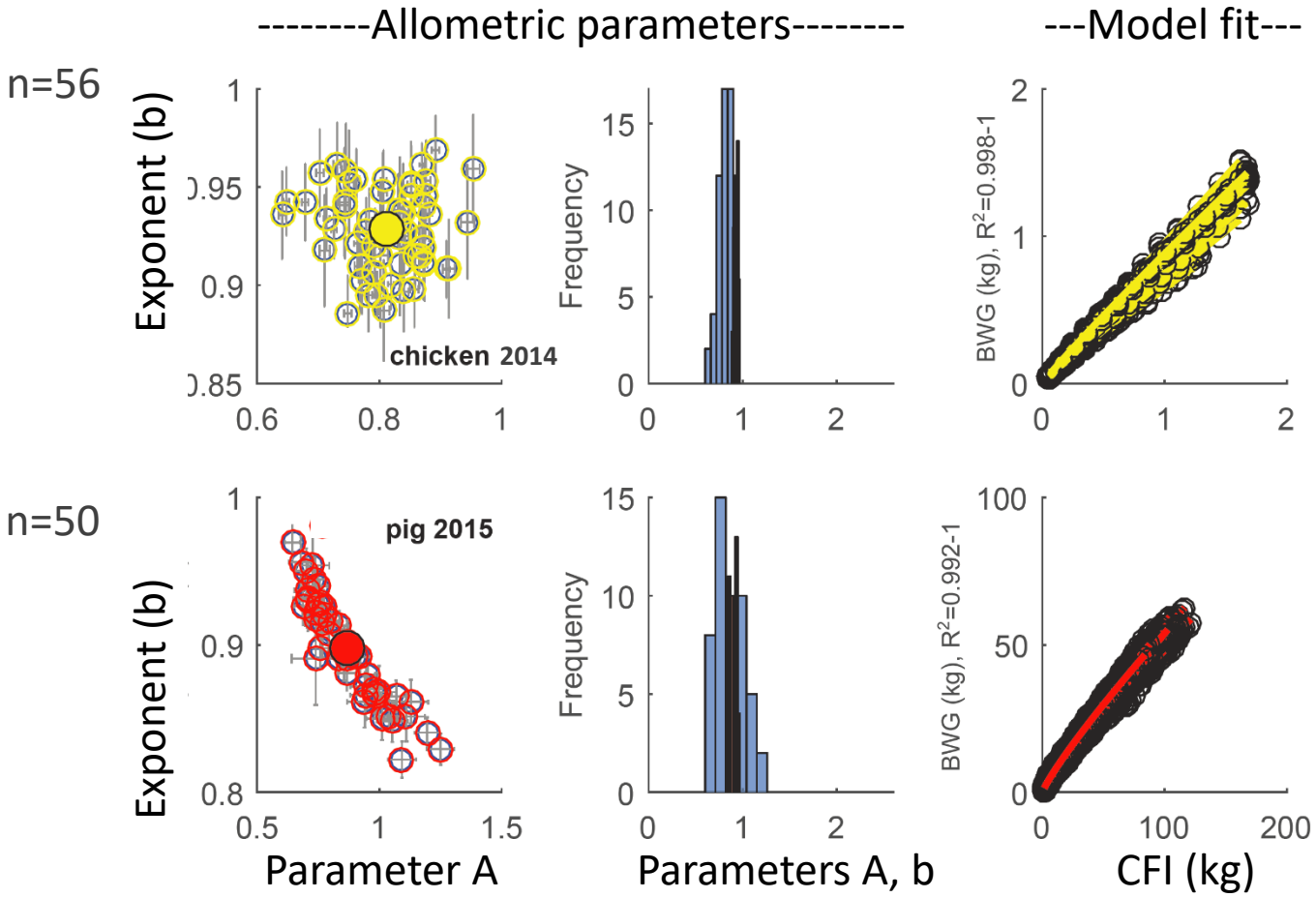
- allometry changes to an asymptotic curve as growth slows down
  - CFI continues to increase when BW reaches maturity - all requirements other than growth

Interpretation



- Mass conservation: biomass gain and intake must be related
- Gain < Intake <= mass losses (digestion and net fluid exchanges)
- Allometry quantifies
  - growth from intake
  - net mass exchanges with environment
- Other allometries during growth, e.g.
  - between body parts, or size and metabolic rate (Kleiber 1932)

Fitting the individual data - chickens & pigs



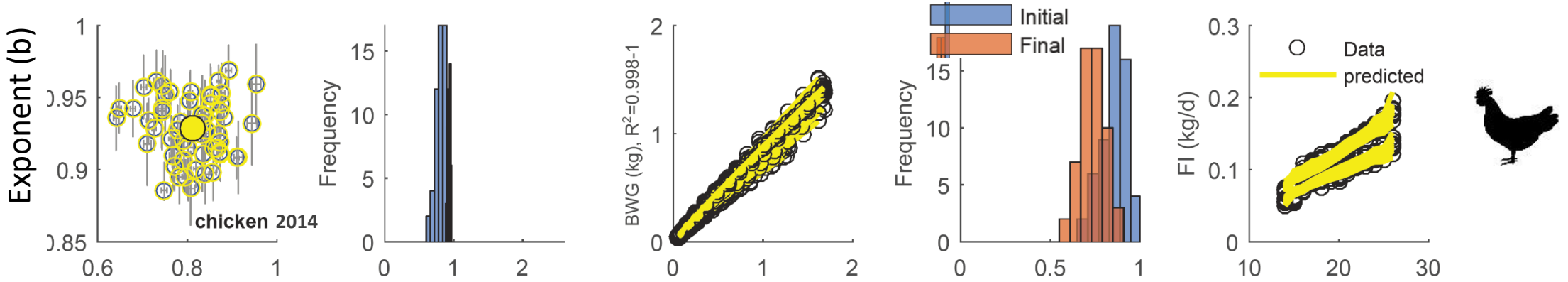
○ = individual parameters;
\+ = 95% Confidence interval;
● = population average

=> Some individual variation – high goodness of fit (R^2 >0.992)

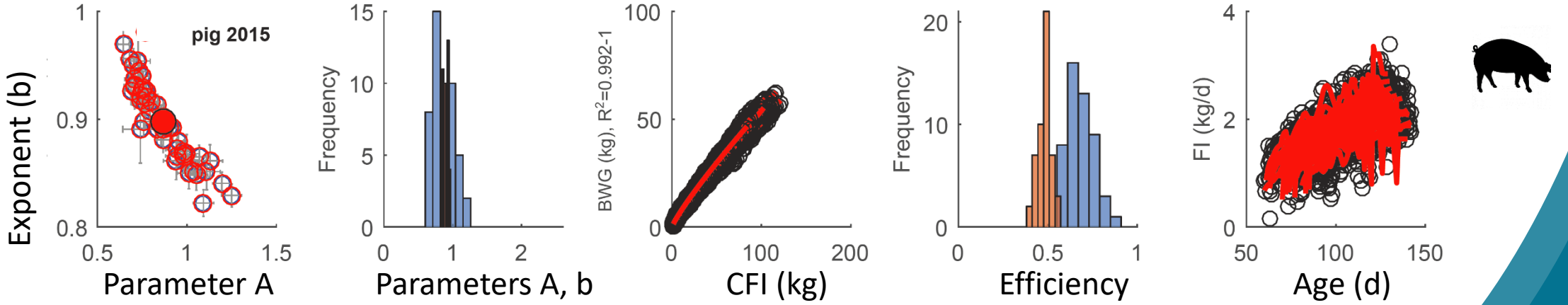
Fitting the individual data - chickens & pigs

--------Allometric parameters-------- ---Model fit--- ----------Predictions----------

n=56



n=50

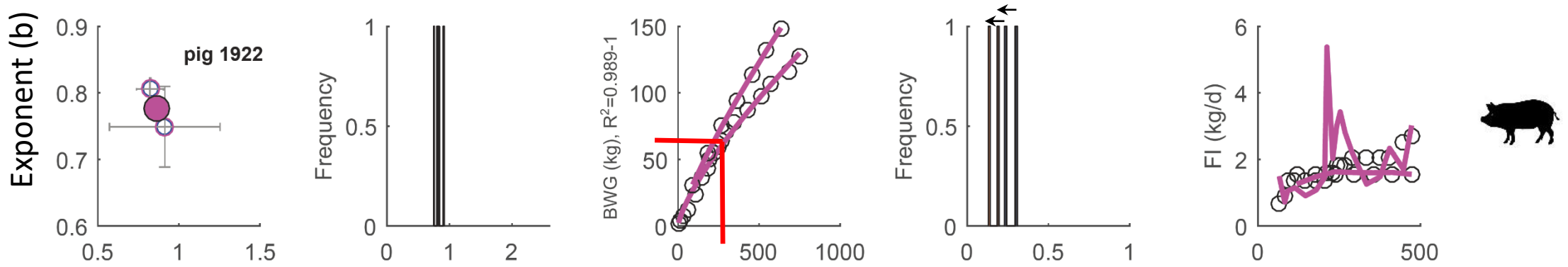


=> Efficiency drops with age – Daily feed intake

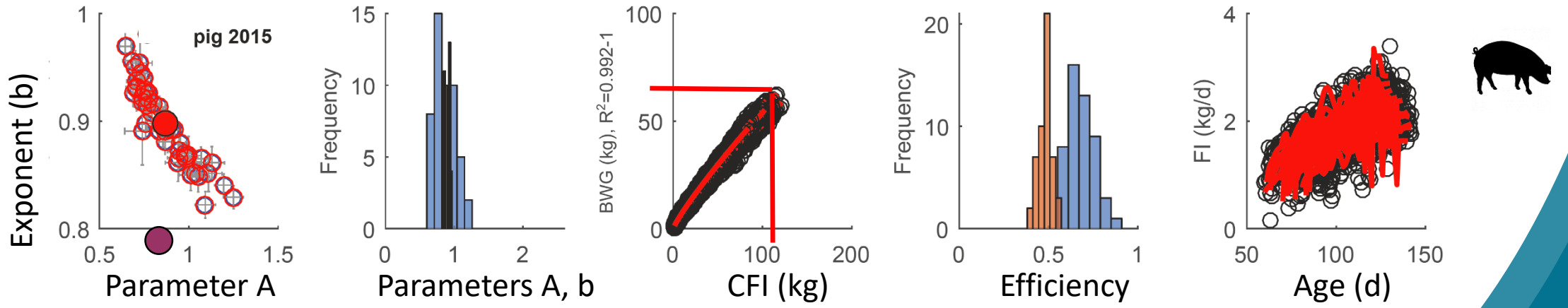
Fitting the individual data - pigs 2015 & 1922

--------Allometric parameters-------- ---Model fit--- ----------Predictions----------

n=2



n=50



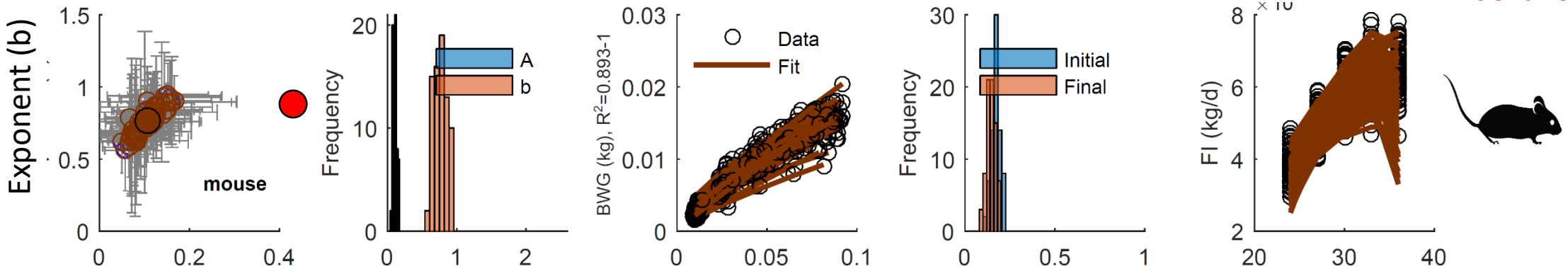
=> Old breeds: lower b & less efficient => suggests b relates to efficiency

Later growth (earlier part of) - mice & rabbits

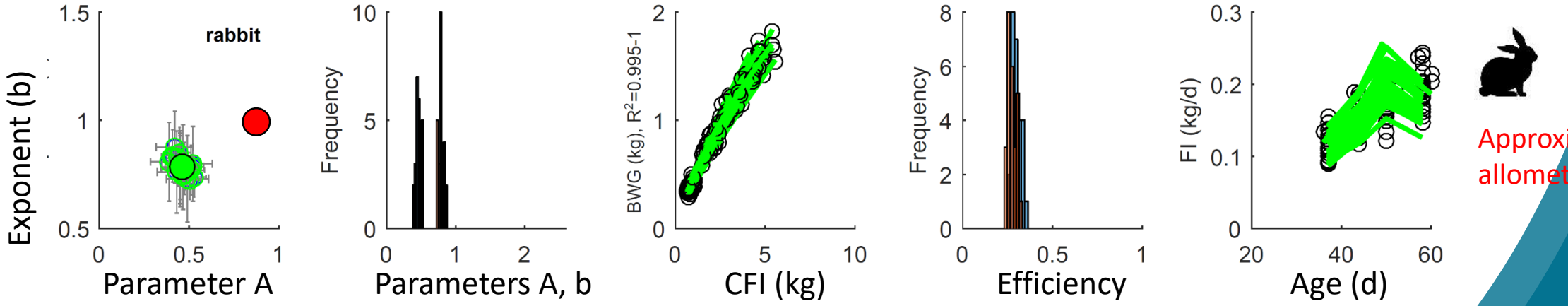
--------Allometric parameters-------- ---Model fit--- ----------Predictions----------

R^2 - less accurate fit of all species

n=75



n=26



Approximately allometric

=> Suggests A relates to size – lower Eff and b, suggest b relates to efficiency

Summary



- Allometry held for different species, breeds, over long-term selection
  - high accuracy of fit to datasets (R^2 and residuals)
- Intuitive (mass gain, losses), interpretable parameters (efficiency, size)
- During early growth, fitted better than Spillman's model,
  - suitable for the full growth trajectory, but allometry is more accurate up to maximum growth
- Relationship needs modification for late growth (work in progress)
  - but for most livestock (except reproducing females) production occurs during early growth

Discussion



- Easy tool to analyse empirical data:
  - FI from weight data, or vice-versa
  - Efficiency and FCR
  - Breeding: parameters could be partially heritable
- While fitted ad libitum intake, and individuals (trait correlations)

Also supported for restricted intake and when fitting pooled data

- pooled-data estimates may be less accurate and meaningful

Thank you for listening!

Supported by

Horizon 2020
European Union Funding
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Spare slides

Insights from historical data - cattle breeds

Taylor 1985,
"Use of genetic-size scaling…."

Similar curvilinear shape during early growth
e.g. first grazing season

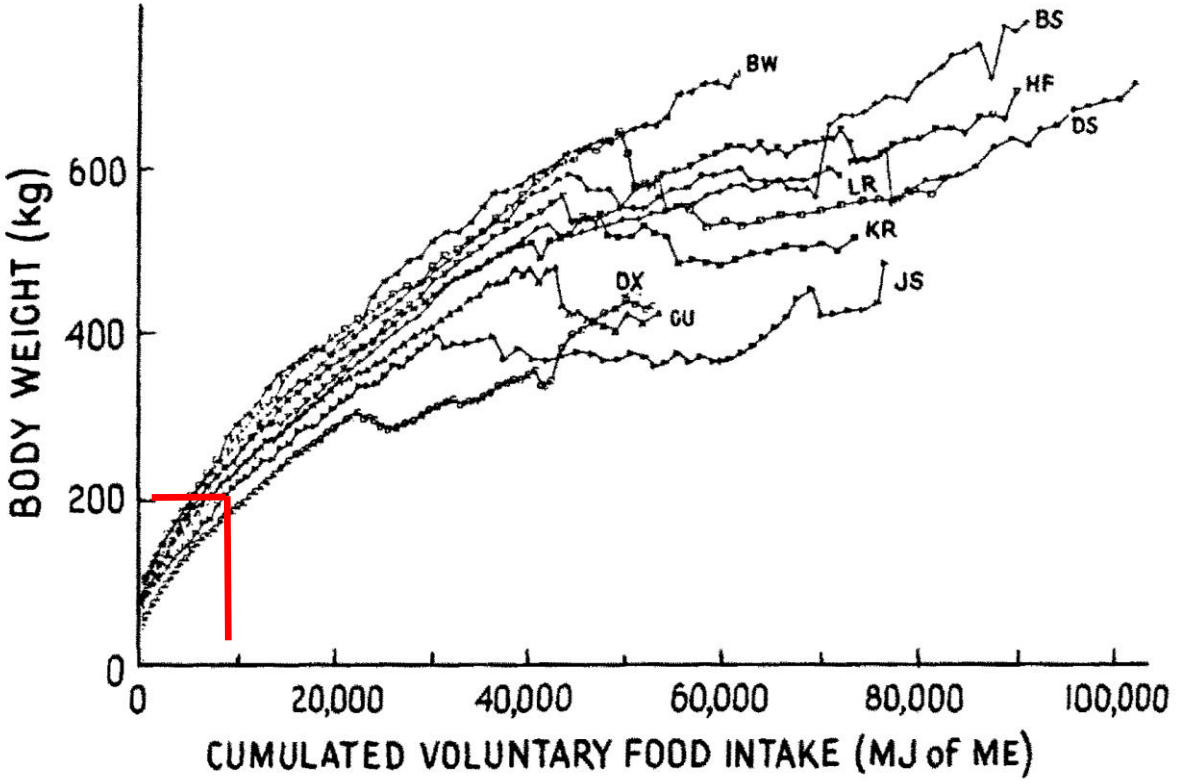


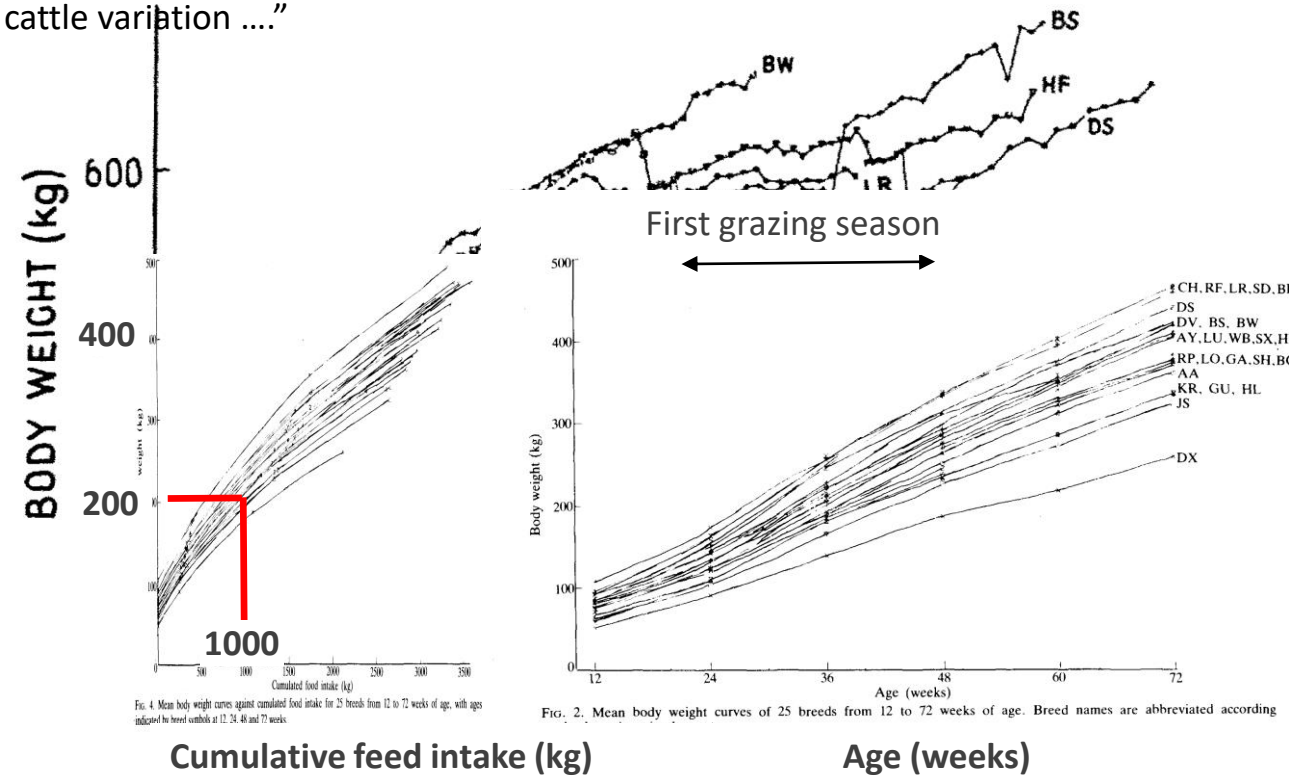
Figure 14. Breed comparisons of body weight in relation to cumulated voluntary food intake for cattle

Insights from historical data - cattle breeds

Thiessen, Taylor, Murray 1984,
"Multibreed comparisons of British cattle variation …."

Similar <u>curvilinear shape during early growth</u>
e.g. first grazing season

Before maximum growth

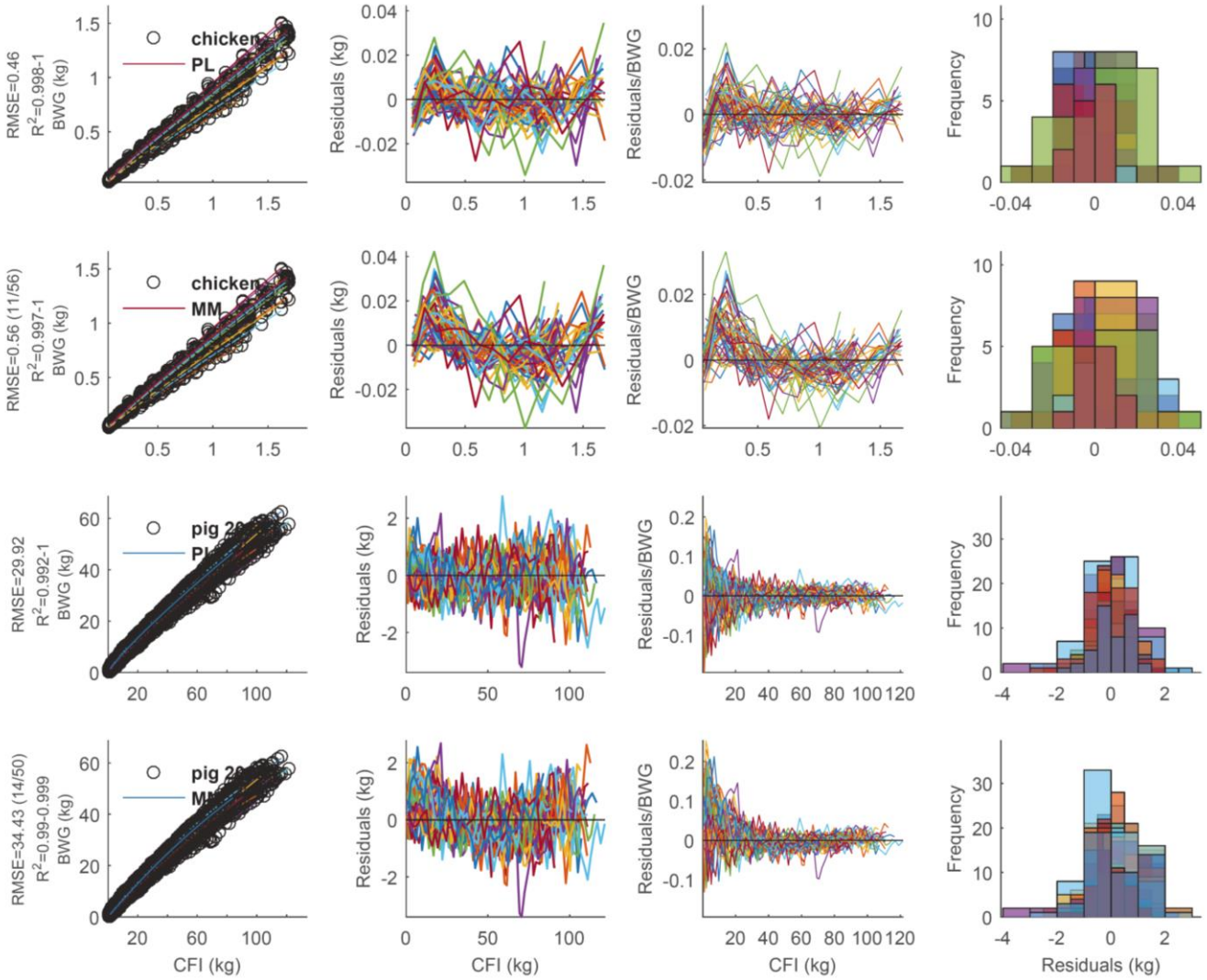


Points to consider in Discussion - Questions

- Mice not meat species, less selected for than rabbits
- Chicken slaughter weight increased, but slaughter age as 1920's
- Allometry doesn't replace mechanistic models that predict requirements and BC, but could be used as input for some – the two types of models are meant for different purposes – descriptive curves (e.g. allometry) useful for genetics, so accuracy important

Allometric & Spillman models – modern breeds

	R^2	RMSE better/total	Residual trend
Allometry	0.998-1	0.46	No
Spillman	0.997-1	0.56 (11/56)	Yes
Allometry	0.992-1	29.92	No
Spillman	0.99-0.999	34.43 (14/50)	Yes



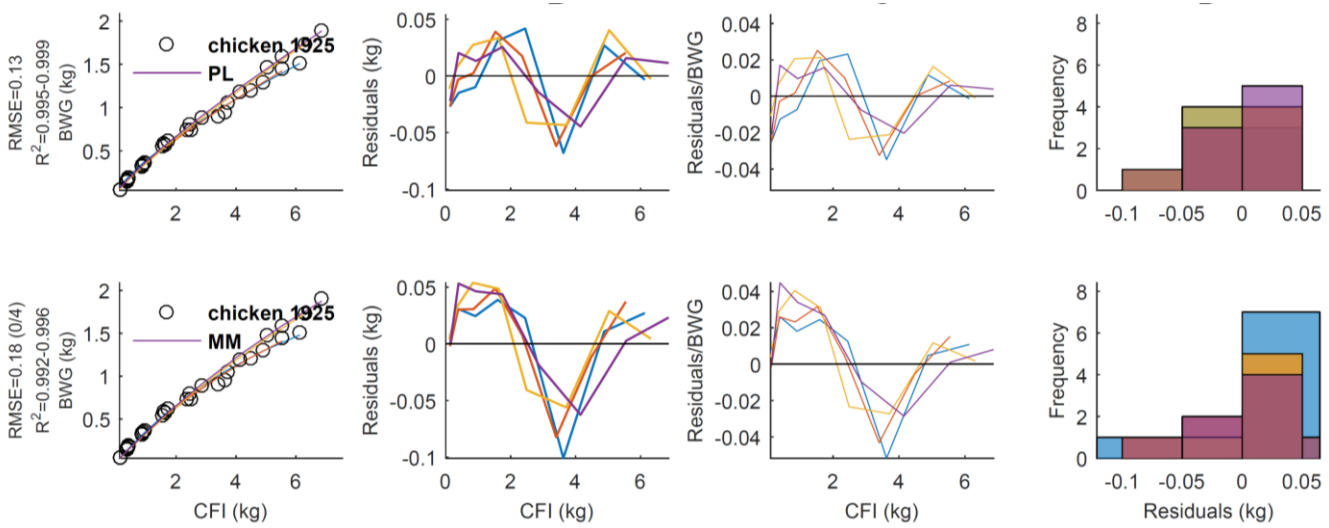
Individual data

PL = power-law
= allometric model

MM = monomolecular
= Spillman's model

Allometric & Spillman models – chickens 1928

	R^2	RMSE better/total	Residual trend
Allometry	0.995-0.999	0.13	maybe
Spillman	0.992-0.996	0.56 (0/4)	maybe



Group data
Jull, Titus 1928,
"Growth of chickens in relation to feed consumption"