University of California, Davis

College of Agricultural and Environmental Sciences/Animal Science

Animal Nutrition & Environment Modeling Applications Laboratory (ANEMAL)

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Postdoc

Principles and Practice of PPFM

https://sites.google.com/view/ppfm-spreadsheet/?authuser=1

Manoel Garcia Neto

Ermias Kebreab

UC Davis/ 2020

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ANIMAL SCIENCE

ANEMAL
Ermias Kebreab, Ph.D.
Animal Nutrition & Environment Modeling Applications Laboratory

Principles and Practice of PPFM

Manoel Garcia Neto

Growth expansion modeling: kinetic energy tool to measure efficacy, efficiency, economicity and effectiveness

Summary

- Models of growth: simply mathematical descriptions of growth trajectories;
- The growth function is necessary, but not sufficient condition for to understand the growth process;
- First principle of energy: balance of energy between production of new biomass and maintenance of existing biomass;
- Action: allows to complete the understanding of the growth models.

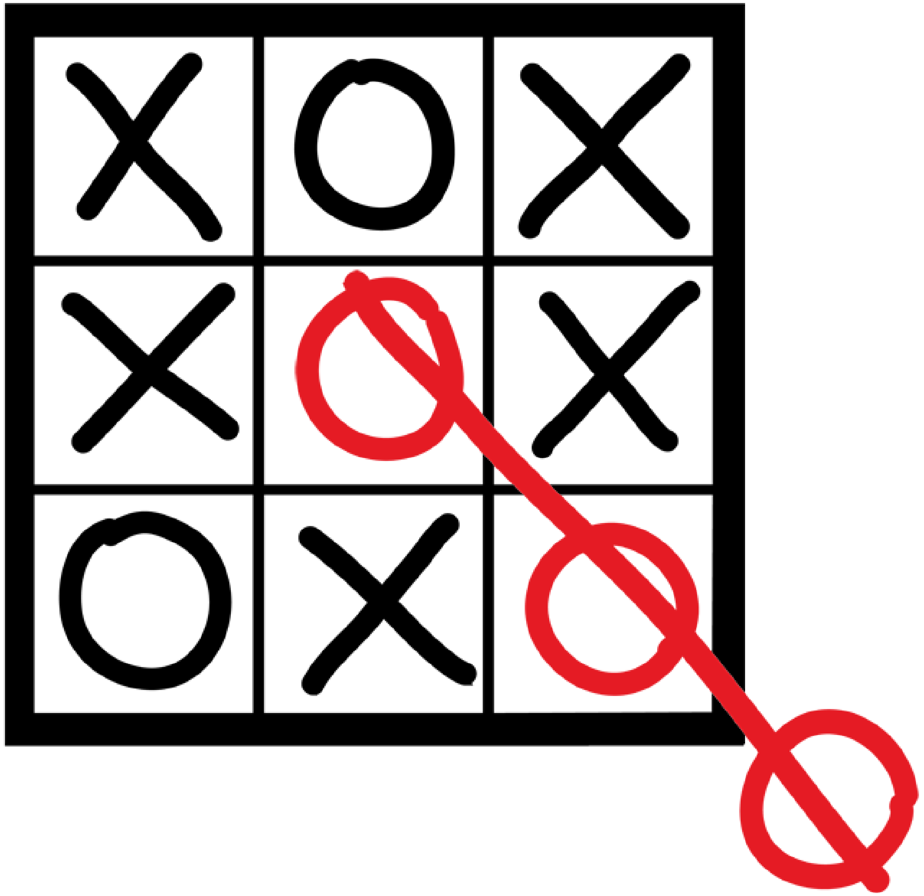
California Driver Handbook - Visual Search

https://www.dmv.ca.gov/portal/dmv/detail/pubs/hdbk/scanning

The shaded areas are your blind spots.

What is the blind spot of my research?

THINK OUTSIDE THE BOX



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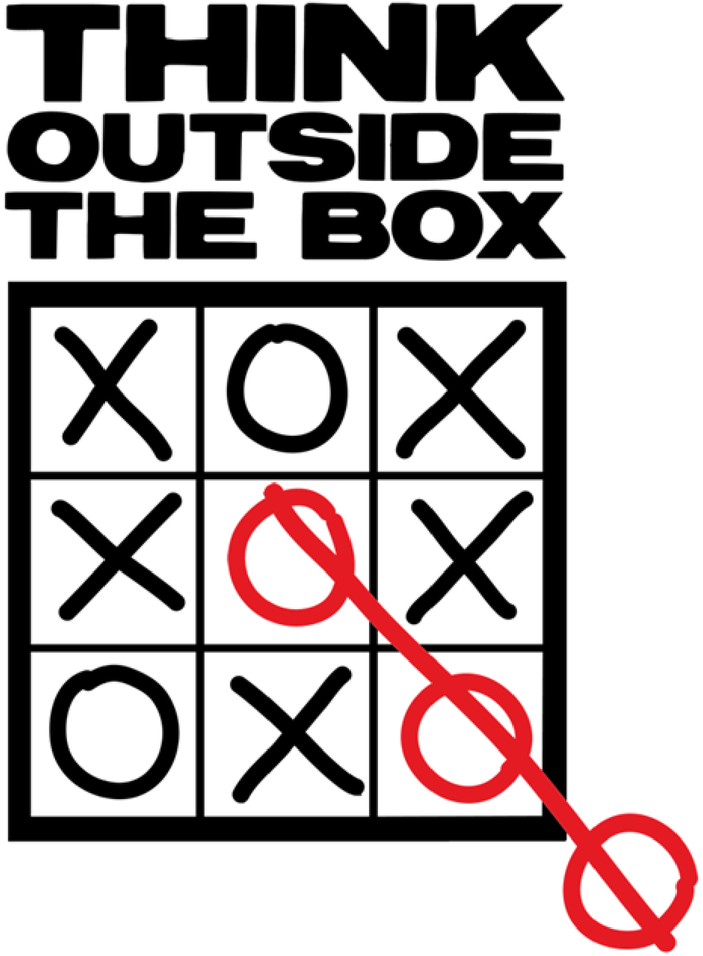

'ac. Agr., Kyushu Univ., **51** (2), 285–287 (2006)

Introducing Viewpoints of Mechanics into Basic Growth Analysis – (I) Three Aspects of Growth Mechanics compared with Three Laws of Motion –

Masataka SHIMOJO*, Kentarou IKEDA[1], Yoki ASANO[2], Reiko ISHIWAKA[3], Hiroyuki SATO[4], Yutaka NAKANO[5], Manabu TOBISA[6], Noriko OHBA[7], Minako EGUCHI[8] and Yasuhisa MASUDA

Laboratory of Animal Feed Science, Division of Animal Science, Department of Animal and Marine Bioresource Sciences, Faculty of Agriculture, Kyushu University, Fukuoka 812–8581, Japan

(Received June 30, 2006 and accepted July 24, 2006)

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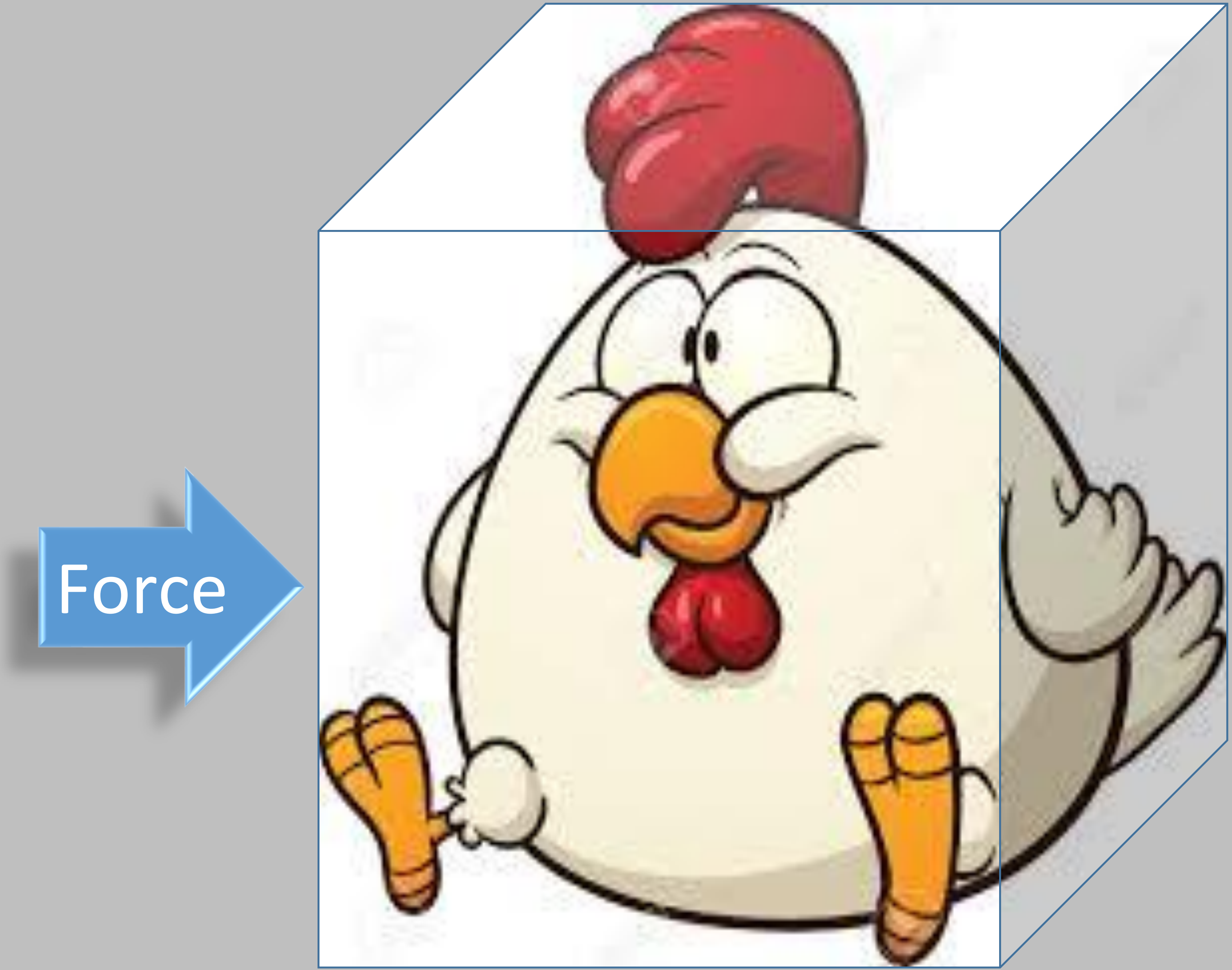
Introducing Viewpoints of Mechanics into Basic Growth Analysis – (I) Three Aspects of Growth Mechanics compared with Three Laws of Motion –

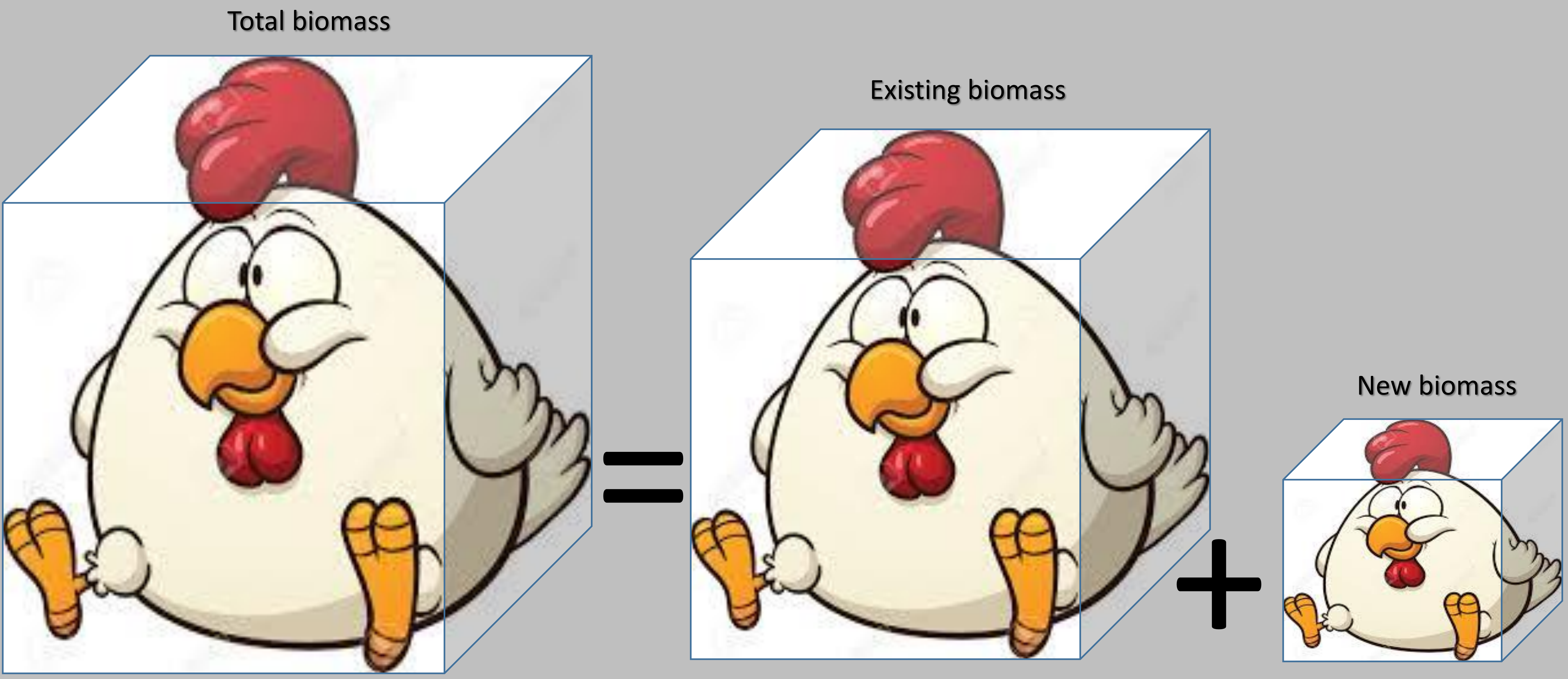
object. This is the second law of three laws of motion, namely Newton's equation of motion (Kawabe, 2006) given by

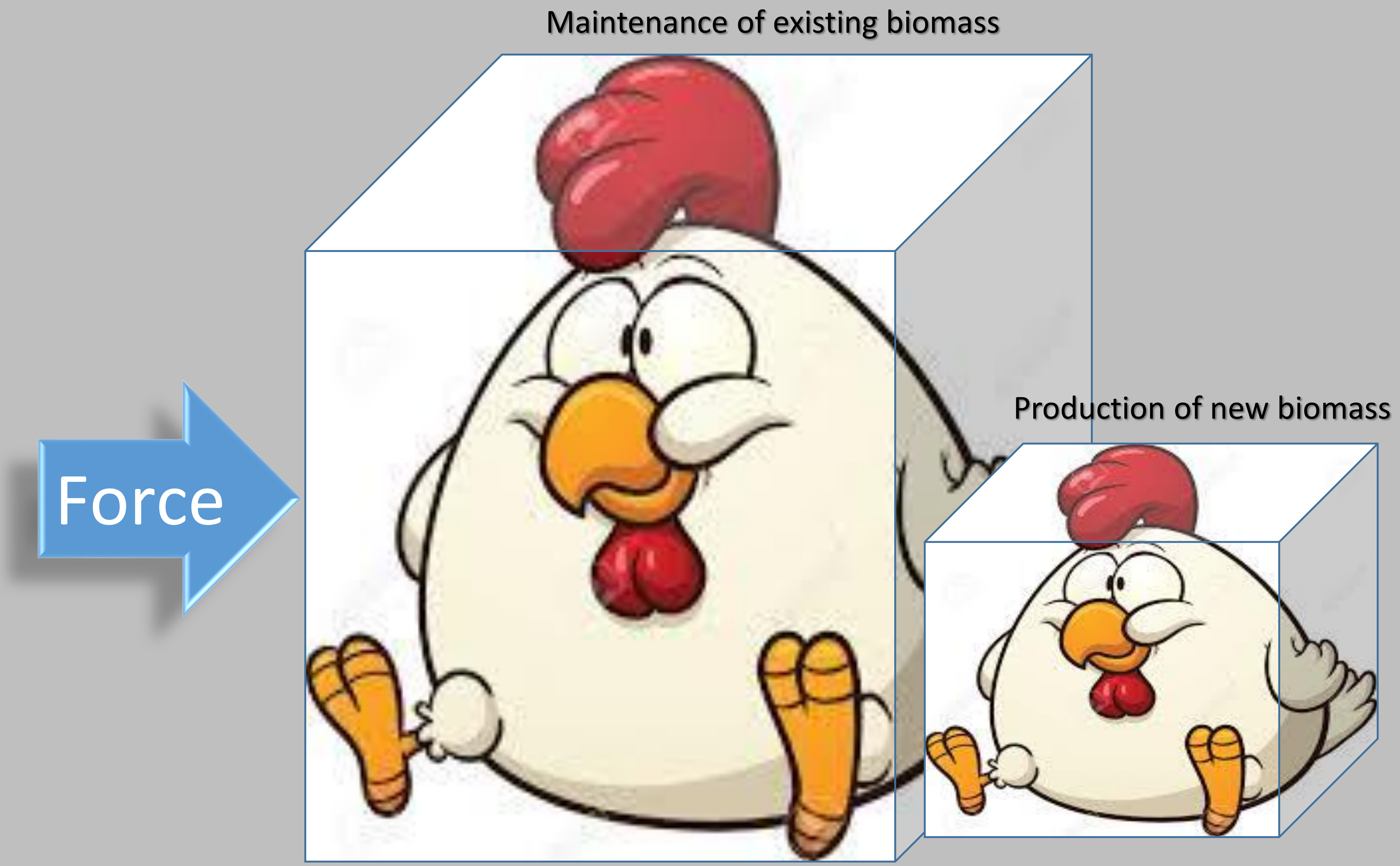
$$F = m\ a, \tag{7}$$

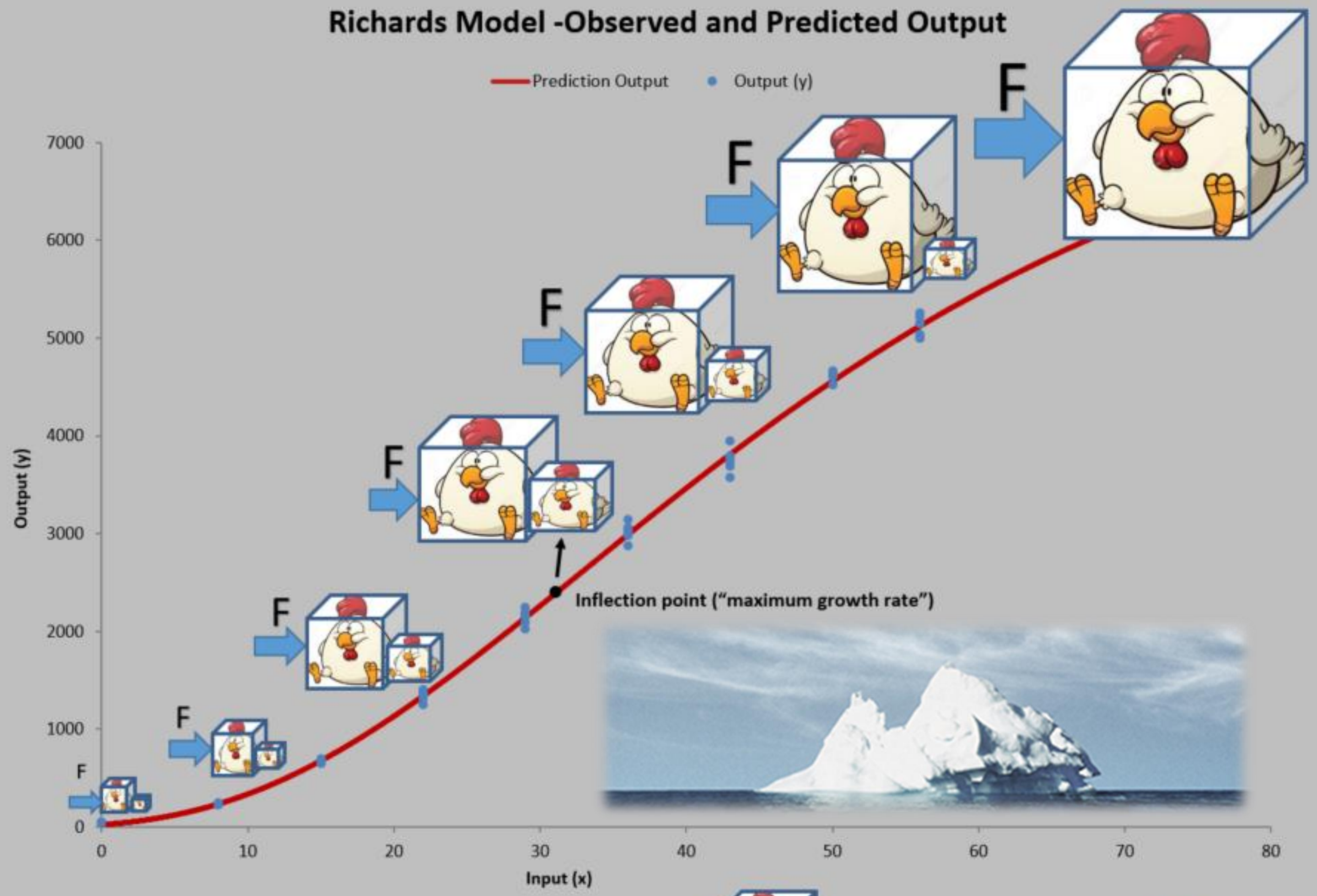
where m = mass of an object, a = acceleration, F = force. Comparing equations (6) and (7) suggests that $(AGR)^2$ looks like force that gets involved in the growth. This

Total biomass

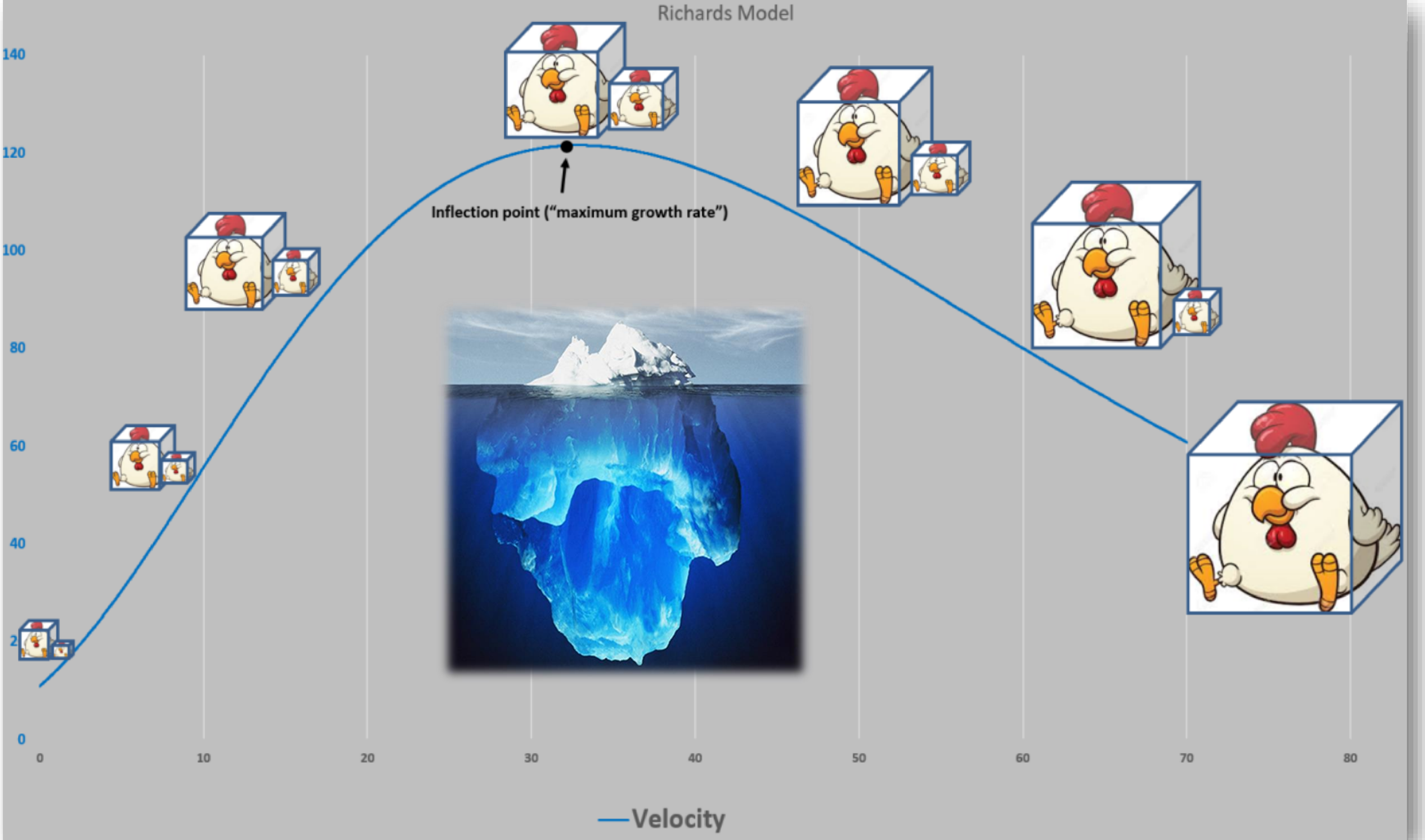



Total biomass
=
Existing biomass
+
New biomass

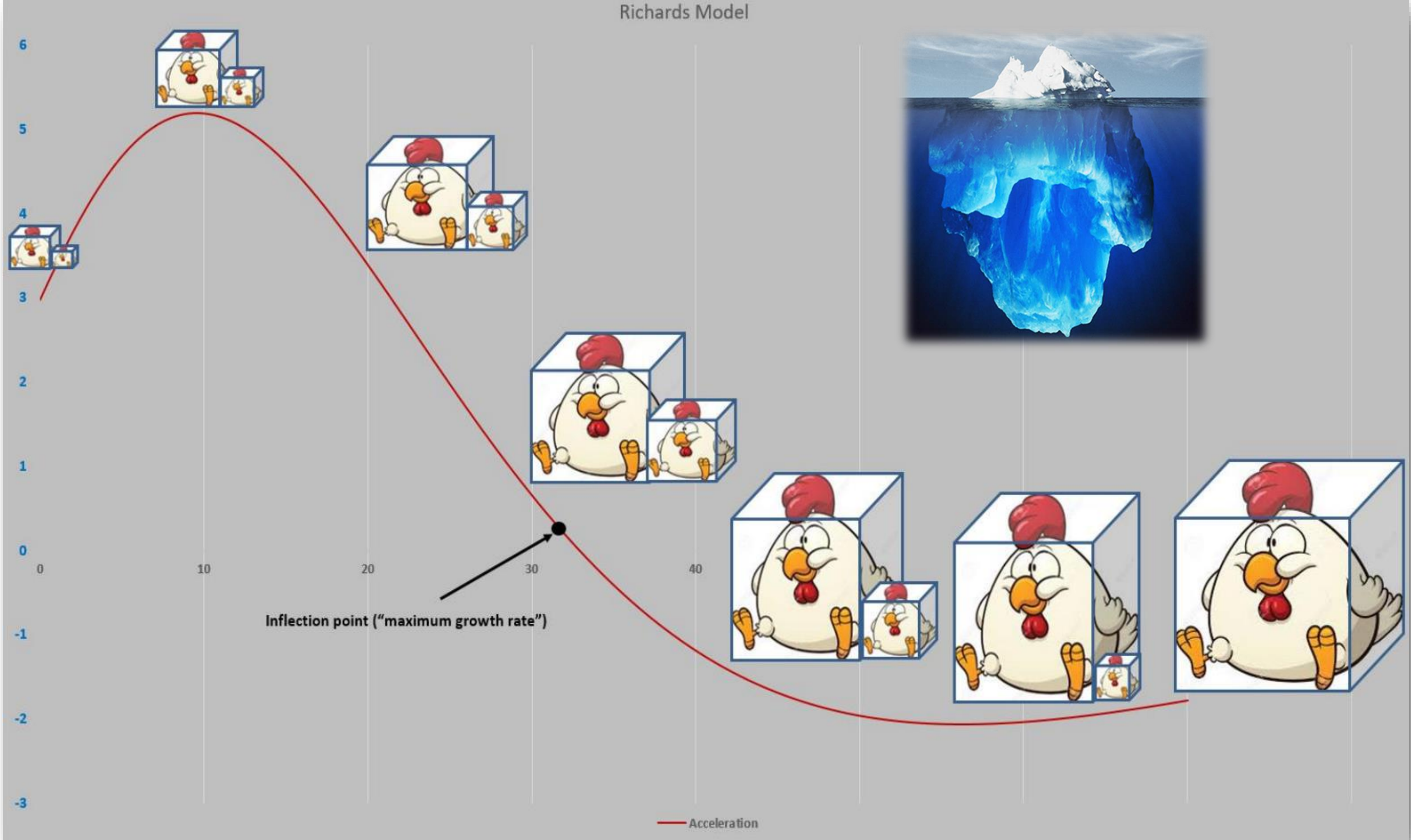

Maintenance of existing biomass
Production of new biomass
Force



F= metabolic forces of catabolism ( ) and anabolism ( )



Richards Model
140
120
100
80
60
40
0
0
10
20
30
40
50
60
70
80
Inflection point ("maximum growth rate")
Velocity


Richards Model
6
5
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
Inflection point ("maximum growth rate")
Acceleration

$F = m * a_c$

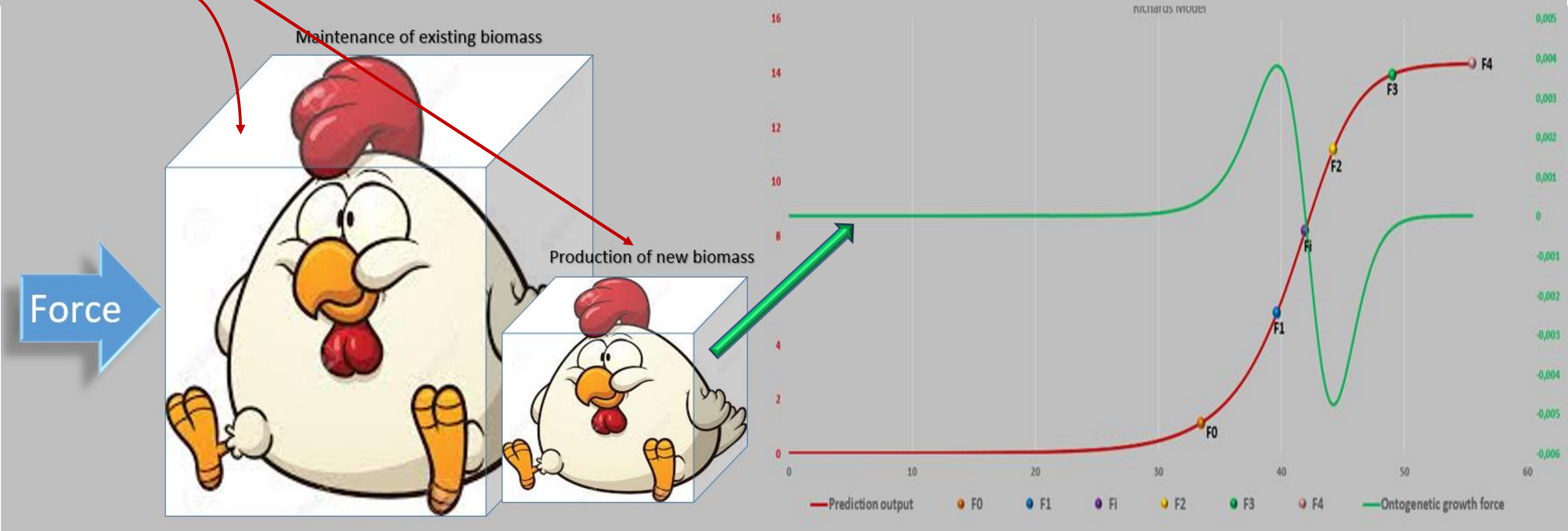
$F = (m_1 + m_2) * a_c$

$F = m_1 * a_c + m_2 * a_c$

$m_1 * a_c$ = Ontogenetic maintenance force

$m_2 * a_c$ = Ontogenetic growth force

§ mass (m_1 and m_2) can be used to determine the ontogenetic maintenance and growth forces



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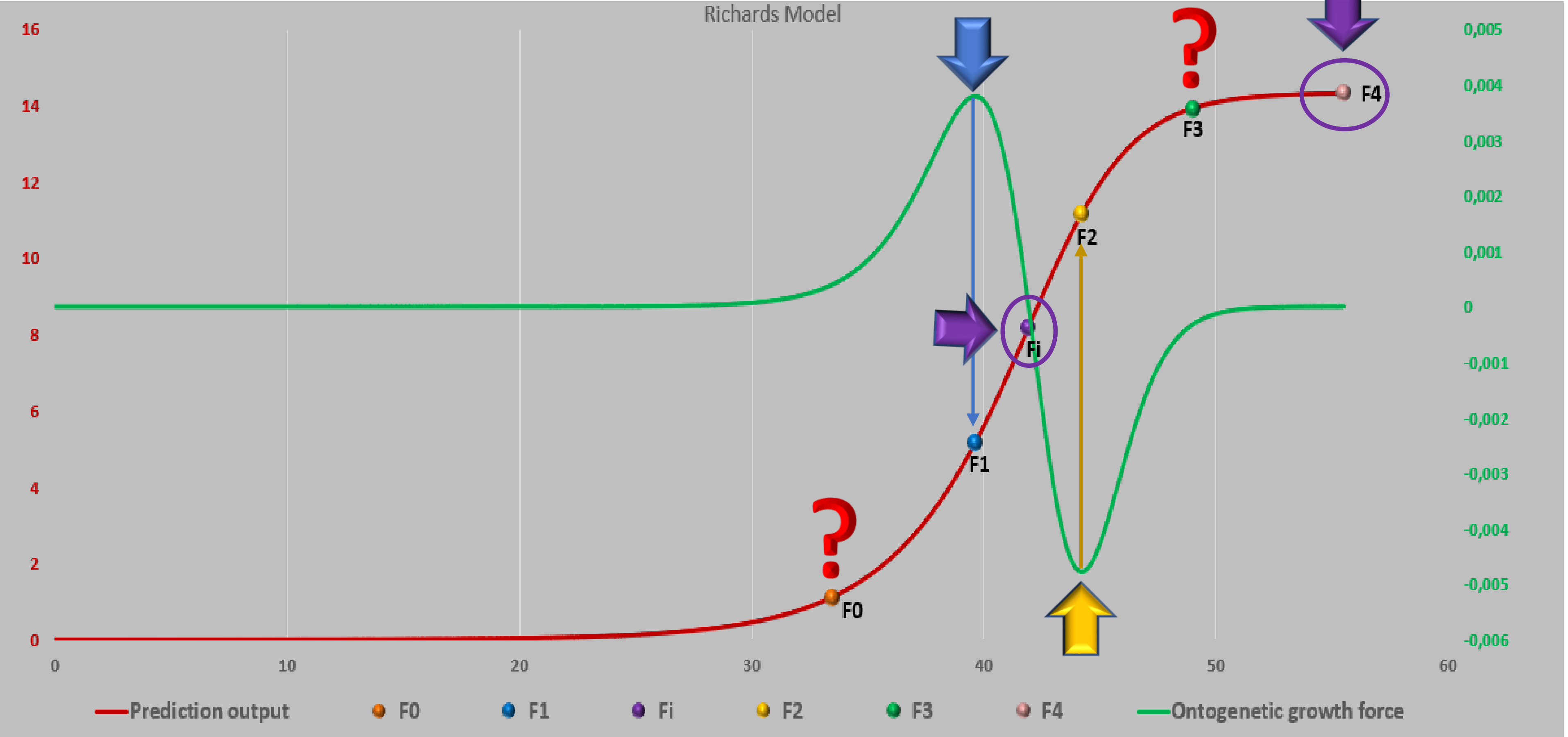

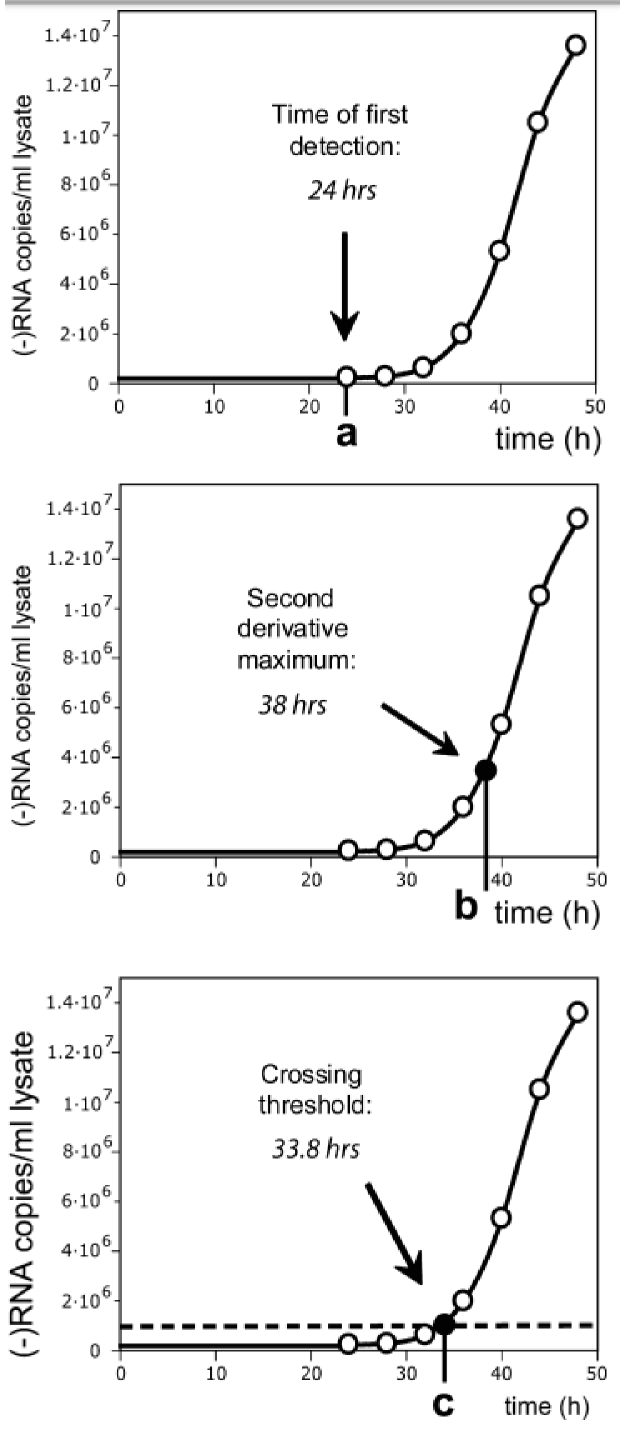

regorczyk, A. "Richards plant growth model." Journal of Agronomy and Crop Science 181.4 (1998): 243-247.

HIMOJO, Masataka et al. Introducing Viewpoints of Mechanics into Basic Growth Analysis-(I) Three Aspects of Growth Mechanics compared with Three Laws of Motion. JOURNAL-FACULTY OF AGRICULTURE KYUSHU UNIVERSITY, v. 51, n. 2, p. 285-287, 2006.

heory of growth based on first principles of energy conservation and allocation

How the energy is allocated between growth (production) and maintenance during ontogeny:

= Ontogenetic metabolic force

	Ontogenetic growth force	Input	Output
F_0=	0,000394135	33,483	1,118
F_1=	0,003786046	39,625	5,164
F_i =	0	41,925	8,189
F_2=	-0,00477176	44,213	11,167
F_3=	-0,000323525	48,989	13,930
F_4=	-6,30245E-07	55,497	14,338

A mathematical approach toward defining and calculating the duration of the lag phase

Robert L. Buchanan [1], Miriam L. Cygnarowicz [2]

Show more

https://doi.org/10.1016/0740-0020(90)90029-H

$$\mathrm{LPD} = M - (1/B),$$

LPD = lag phase duration
M = time (h) when culture achieves its maximum *velocity*, **B** = relative *velocity* at time M.

a_c=acceleration

$F=m*a_c$

$$\mathrm{LPD}_a = M_a - (1/B_a)$$

M = time (h) when culture achieves its maximum or minimum*acceleration*, **B** = relative *acceleration* at time M.

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Journal of Virological Methods

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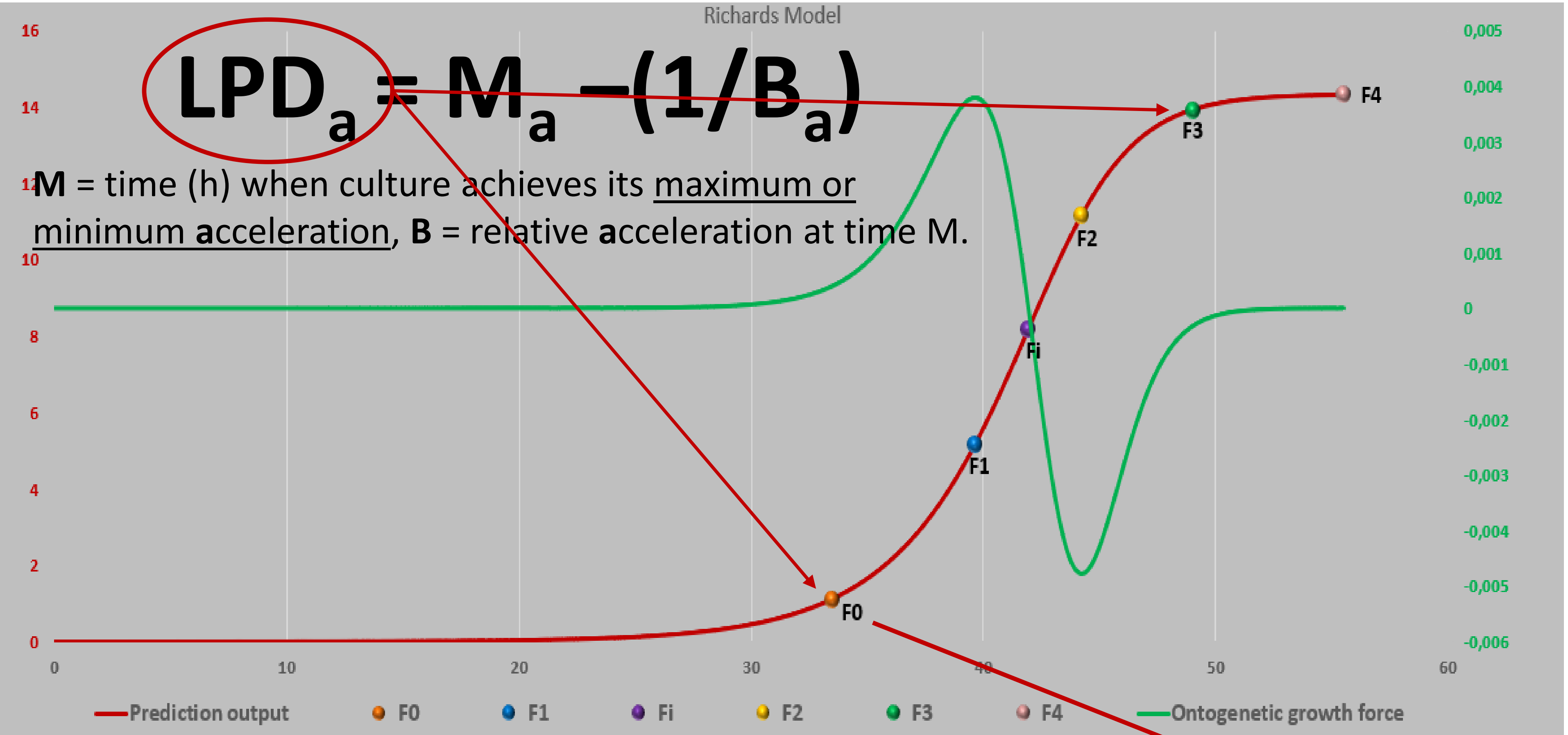
M = time (h) when culture achieves its maximum or minimum acceleration, **B** = relative acceleration at time M.



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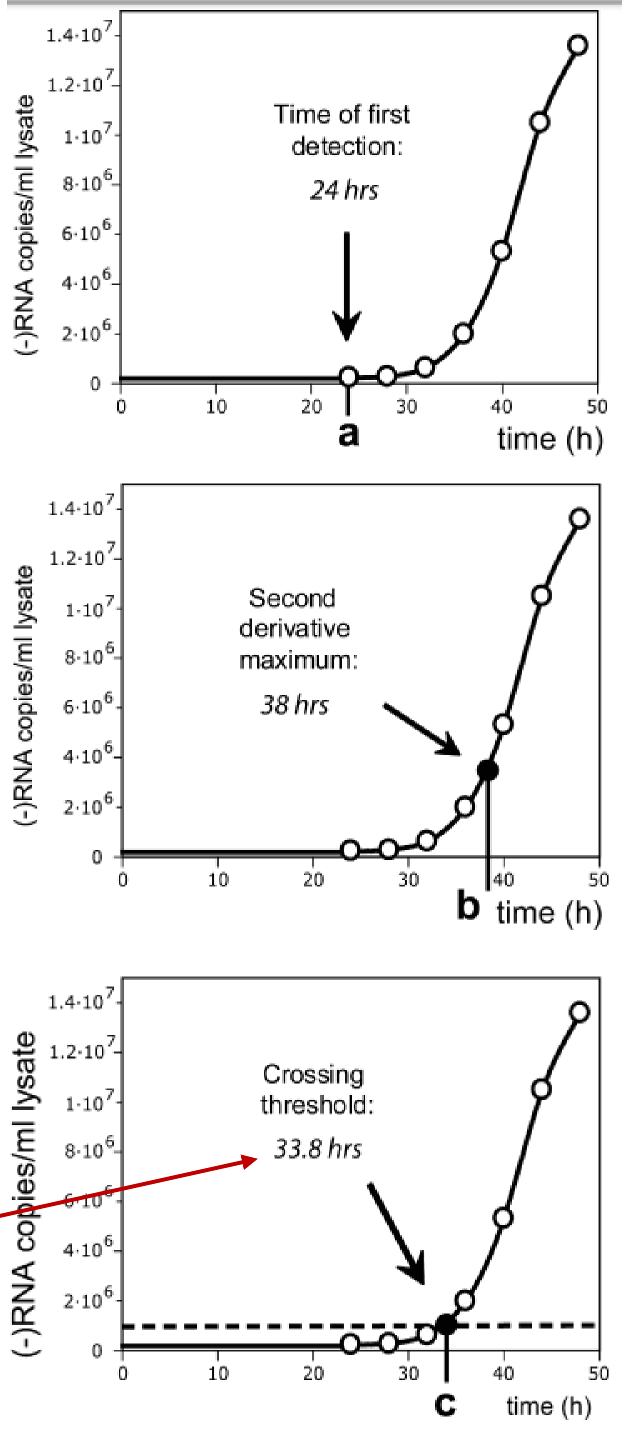

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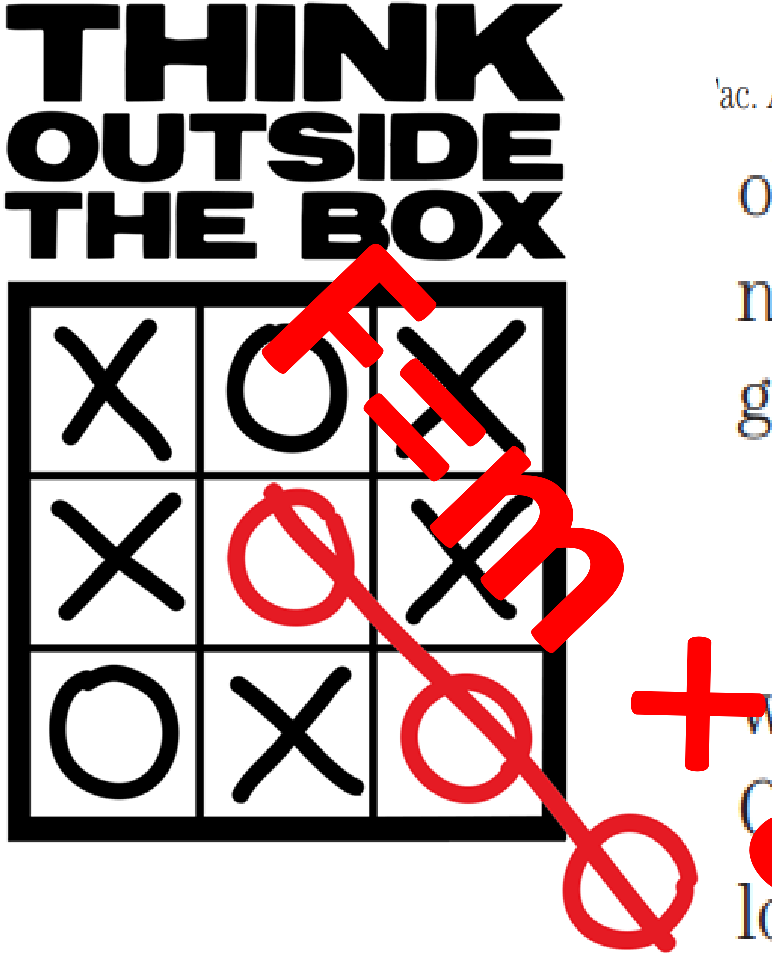

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$$F = m\ a, \tag{7}$$

where m = mass of an object, a = acceleration, F = force. Comparing equations (6) and (7) suggests that $(AGR)^2$ looks like force that gets involved in the growth. This http://hyperphysics.phy-astr.gsu.edu/hbase/units.html

Physical Units

Mechanics is the branch of physics in which the basic physical units are developed. The logical sequence is from the description of motion to the causes of motion (forces and torques) and then to the action of forces and torques. The basic mechanical units are those of

MASS, LENGTH, & TIME – { × ÷ }

All mechanical quantities can be expressed in terms of these three quantities. The standard units are the Systeme Internationale or SI units. The primary SI units for mechanics are the kilogram (mass), the meter (length) and the second (time). However if the units for these quantities in any consistent set of units are denoted by M, L, and T, then the scheme of mechanical relationships can be sketched out.

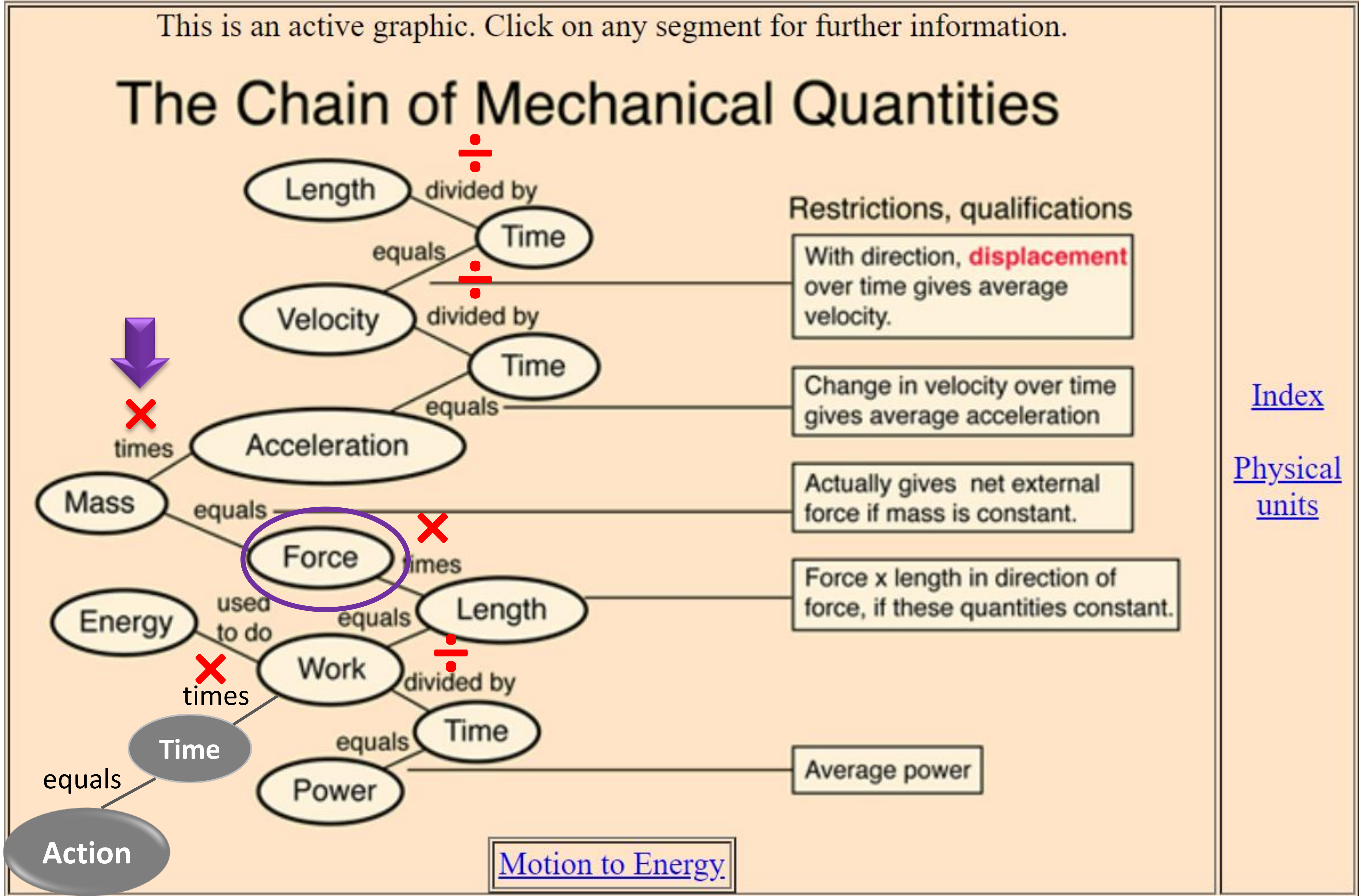
Chain of mechanical quantities	Development of mechanical units	Table of units	Unit conversions

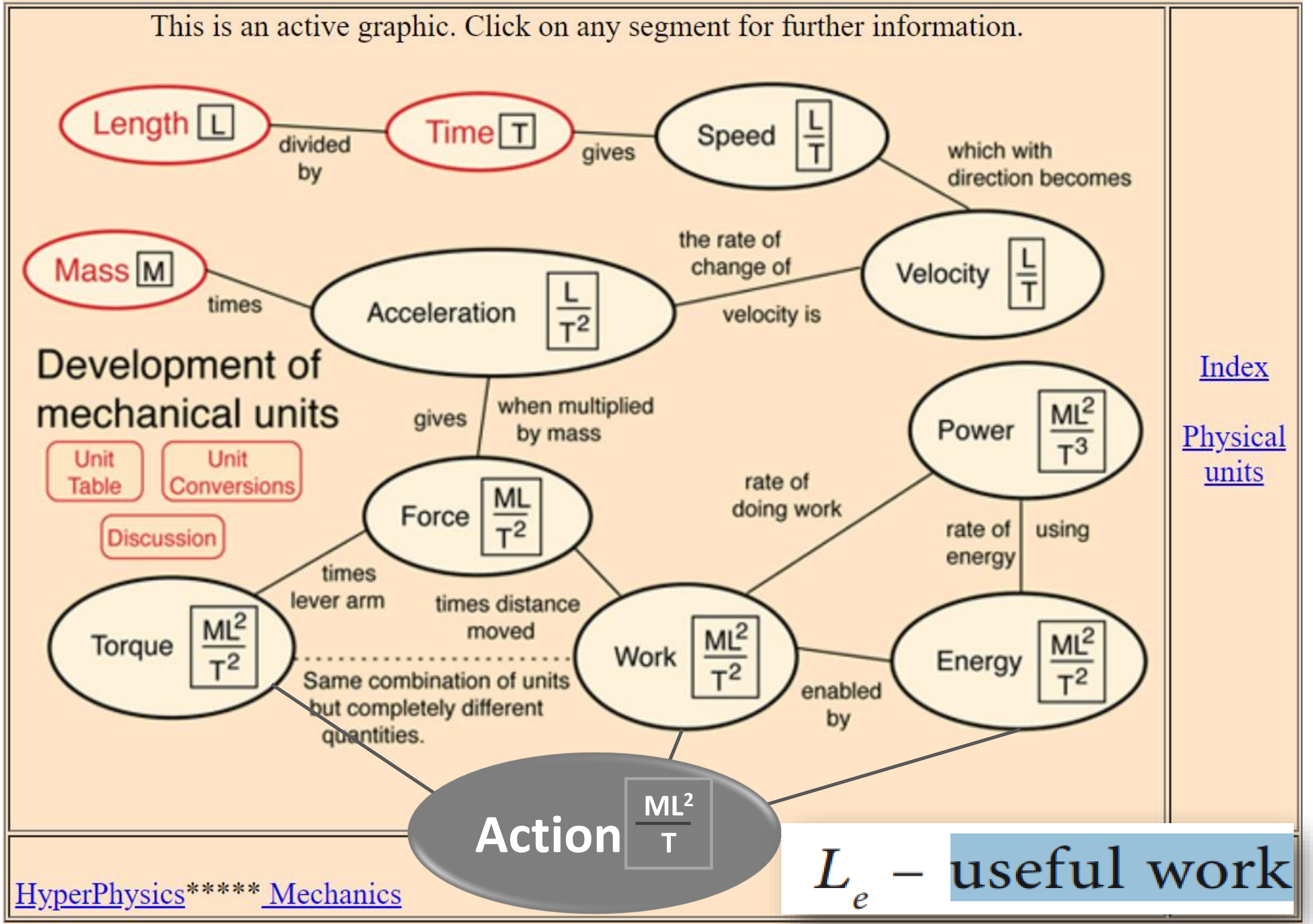
Comment on significant digits	Dimensional analysis

Motion to Energy

A brief overview of time.

http://hyperphysics.phy-astr.gsu.edu/hbase/units.html

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Length L
divided by
Time T
gives
Speed L/T
which with direction becomes
Velocity L/T
the rate of change of
velocity is
Mass M
times
Acceleration L/T²
Development of mechanical units
Unit Table
Unit Conversions
Discussion
gives
when multiplied by mass
Force ML/T²
Power ML²/T³
rate of doing work
rate of energy
using
times lever arm
times distance moved
Torque ML²/T²
Work ML²/T²
Energy ML²/T²
Same combination of units but completely different quantities.
enabled by
Action ML²/T
L_e – useful work
Index
Physical units
HyperPhysics***** Mechanics

"x" = Area = Action

PHYSICS BIOLOGY

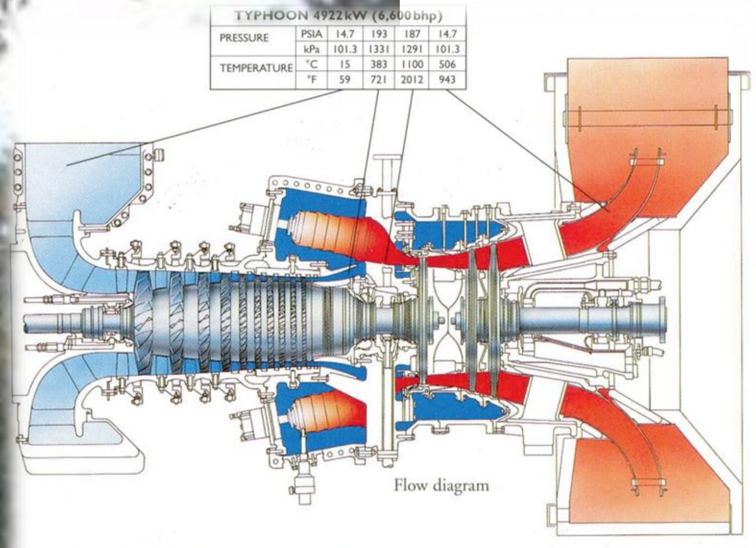
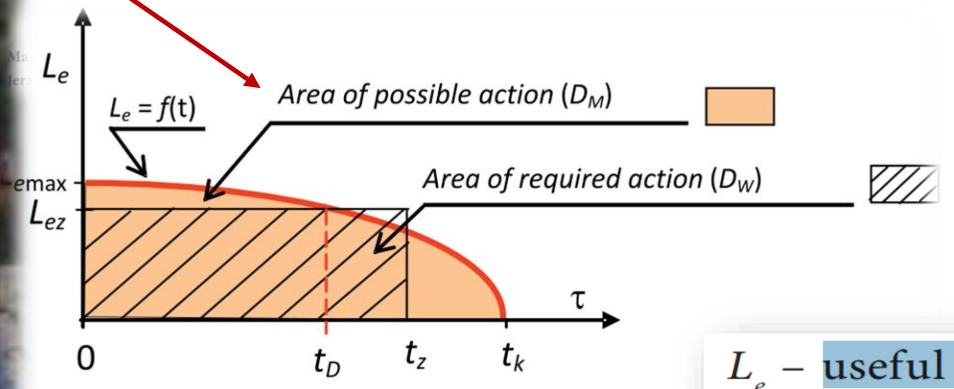


Fig. 1, Cross-section of a sample double-shaft turbine combustion engine,

POLISH MARITIME RESEARCH 4 (92) 2016 Vol. 23; pp. 67-72
10.1515/pomr-2016-0071

OPERATION EVALUATION METHOD FOR MARINE TURBINE COMBUSTION ENGINES IN TERMS OF ENERGETICS



L_e – useful work

Fig. 3. Example case interpretation, where $D_w < D_M$: D_W – action required, D_M – action possible, t_D – operation time of the engine, after which the $D_w = D_M$, t_z – time needed to complete the task, t_k – critical time, after the expiry of which the engine cannot operate, t - operation time

https://scholar.google.com.br/scholar?output=instlink&q=info:k2AH_wFOotYJ:scholar.google.com/&hl=pt-BR&as_sdt=0,5&as_vis=1&scillfp=14314146921196004353&oi=lle

Action principles as determinants of ecosystem structure: the autonomous lake as a reference system

Peter Vanriel and Lionel Johnson

Ecology. 76.6 (Sept. 1995): p1741+. From *Academic OneFile*.

Listen

L_e – useful work

Abstract:

Action in theoretical physics is an abstract quantity describing the overall motion of a system; action has the dimensions of energy x time (in joule-seconds). The Principle of Least Action states that physical systems follow that path for which the action has the least value. By analogy, we hypothesize that, if the principle of least action is universal, ecosystems must be structured on interaction between this principle of least action and an overriding Principle of Most Action. Most action implies energy acquisition, concentration, and conservation. In an autonomous ecosystem a

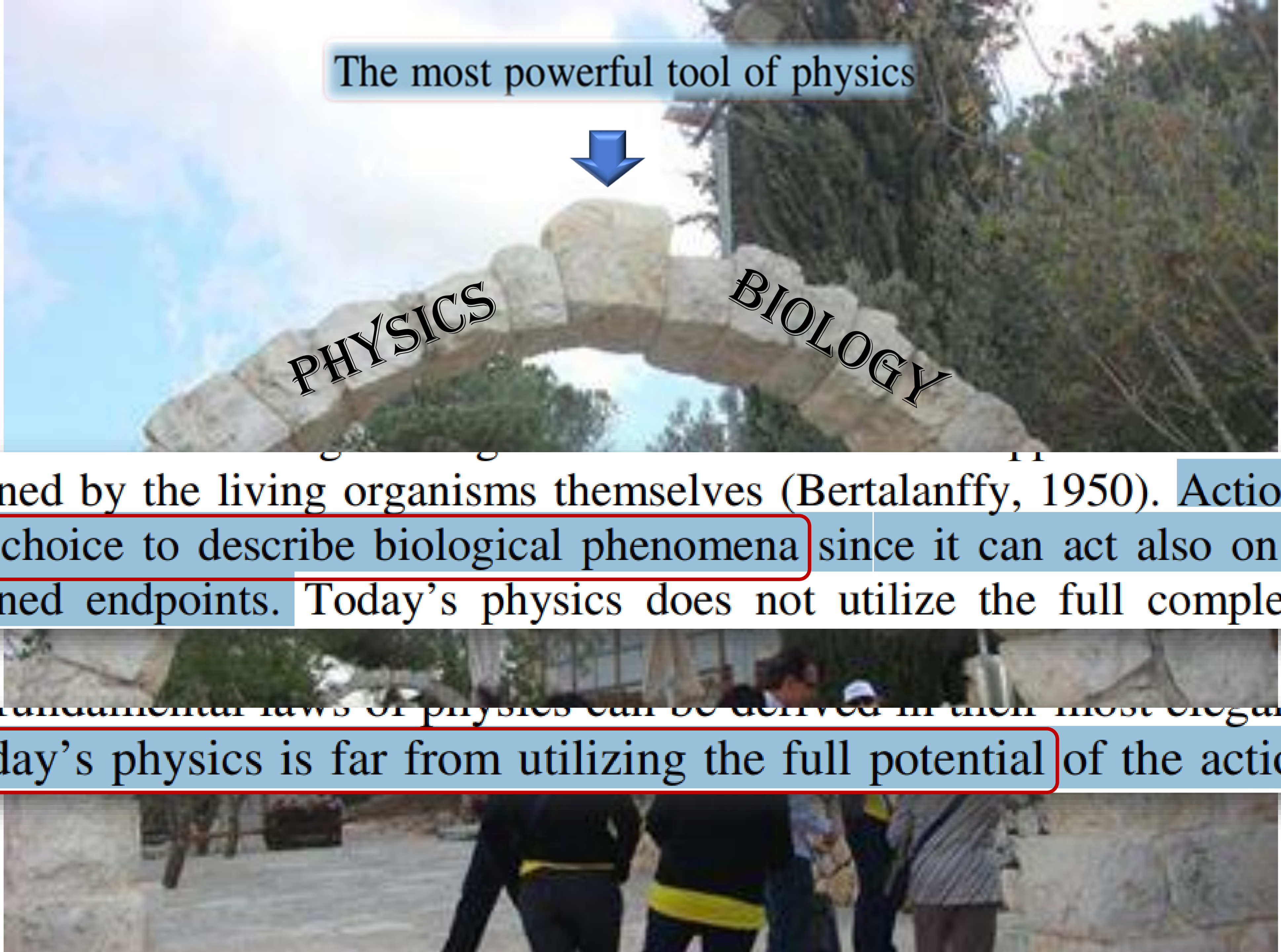
Biological Extension of the Action Principle: Endpoint Determination beyond the Quantum Level and the Ultimate Physical Roots of Consciousness

https://arxiv.org/ftp/arxiv/papers/0802/0802.0601.pdf

Attila Grandpierre
Konkoly Observatory of the Hungarian Academy of Sciences
H-1525 Budapest, P. O. Box 67, HUNGARY
E-mail: grandp@iif.hu

Abstract

With the explosive growth of biology, biological data accumulate in an increasing rate. At present, theoretical biology does not have its fundamental principles that could offer biological insight. In this situation, it is advisable for biology to learn from its older brother, physics. The most powerful tool of physics is the action principle, from which all the fundamental laws of physics can be derived in their most elegant form. We show that today's physics is far from utilizing the full potential of the action principle. This



determined by the living organisms themselves (Bertalanffy, 1950). Action is an ideal tool of choice to describe biological phenomena since it can act also on biologically determined endpoints. Today's physics does not utilize the full complement of the

that today's physics is far from utilizing the full potential of the action principle.

connects it on a fundamental way with biological processes. We show that the biological form of the action principle acts in the realm beyond quantum physics and represents a new frontier of science. It offers integral principles and

Published in: Quantum Mind 2007, Salzburg, Austria, Abstracts
https://www.sbg.ac.at/brain2007/abstracts/concurrents.htm

Integral Aspects Of The Action Principle In Biology And Psychology: The Ultimate Physical Roots Of Consciousness Beyond The Quantum Level

Attila Grandpierre <grandp@iif.hu>
Konkoly Observatory of the Hungarian Academy of Sciences, Budapest, Hungary

During the last centuries it became more and more clear that the highest achievement of modern physics is its most fundamental law, the action principle. The action principle itself is not understood, its physical content is obscure, and its integral character is ignored. Here we consider the nature of action and found it having a biological nature. We point out that the action principle usually takes a minimum value in physical systems, while in biological organism it usually takes its maximal value. Therefore, we could recognize in the already established

https://www.academia.edu/22032221/Integral_Aspects_Of_The_Action_Principle_In_Biology_And_Psychology_The_Ultimate_Physical_Roots_Of_Consciousness_Beyond_The_Quantum_Level

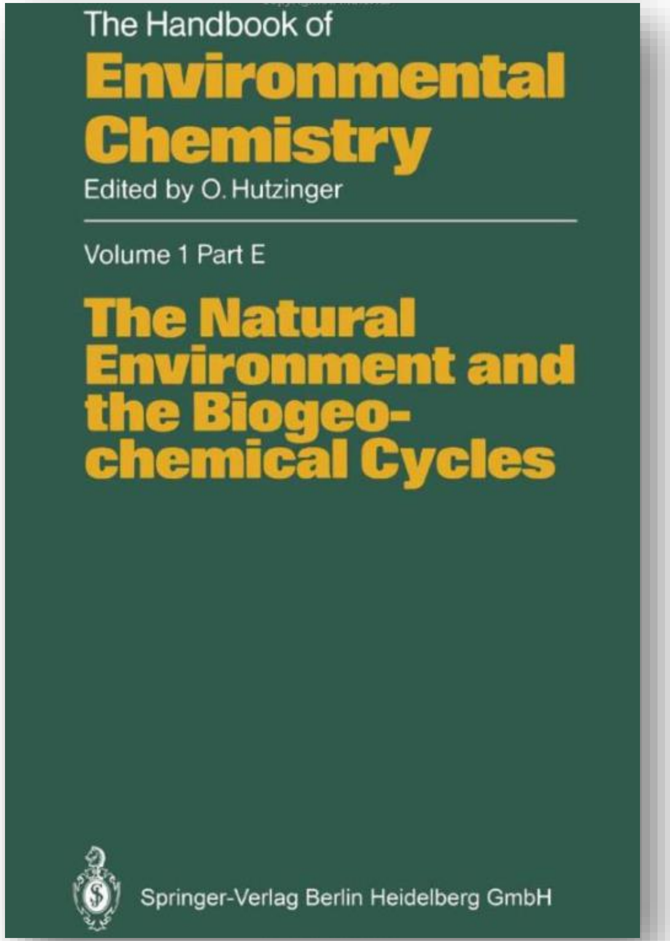
Edited by

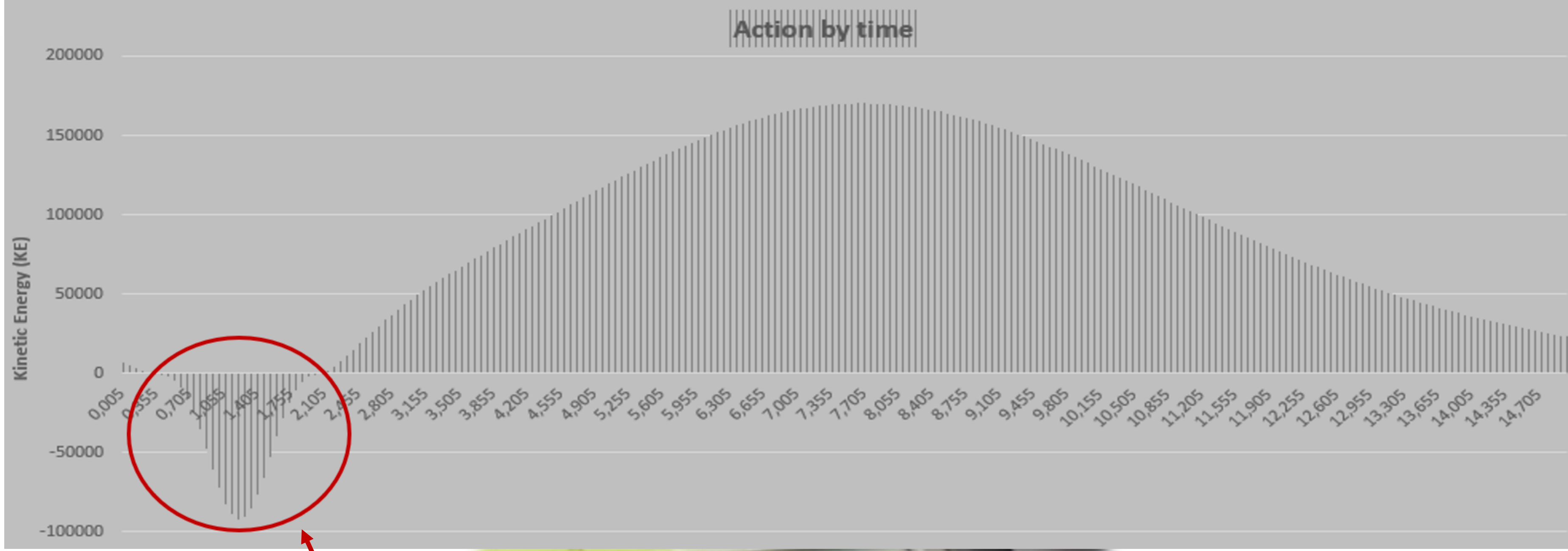
S.E. Jørgensen

Thermodynamics and Ecological Modelling

Least and most action may be regarded as opposing attractors. The end point of "most action" is a state of "crystallization, " a permanent state with no further change. The least action attractor is spontaneous combustion and dissolution in a

The above are important objections, yet as will be seen in subsequent sections, the application of Action Principles provides such an interesting and far-reaching explanation for major biological processes, from ecosystem structure to evolution and natural selection, that I believe it is the physical laws that require extension.





motion. Energy is stored by the continual transformation of kinetic to potential energy and vice versa. At the top of the swing the energy is

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Article

Action Principles as Determinants of Ecosystem Structure: The Autonomous Lake as a Reference System

Peter Vanriel, Lionel Johnson

First published: 01 September 1995 | https://doi.org/10.2307/1940707 | Cited by: 10

Abstract

Action in theoretical physics is an abstract quantity describing the overall motion of a system; action has the dimensions of energy x time (in joule—seconds). The Principle of Least Action states that physical systems follow that path for which the action has the least value. By analogy, we hypothesize that, if the principle of least action is universal, ecosystems must be structured on interaction between this principle of least action and an overriding Principle of Most Action. Most action implies energy acquisition, concentration, and conservation. In an autonomous ecosystem a trophic hierarchy is formed in which, for stability, the action increases at each hierarchical level. We predicted that energy density (in joules per gram), being one of the components of most action, must increase at each level along the food chain. This prediction was tested in Keyhole

rapidly as the constraints allow. Work is done by imposing a time delay on the passage of energy from one state to another, and the result of work is an increase in potential energy in some part of the system. The amount of work done is always the least for the conditions and constraints prevailing, and the slower it is done the more efficiently it is performed. To e

must dominate system behavior in th

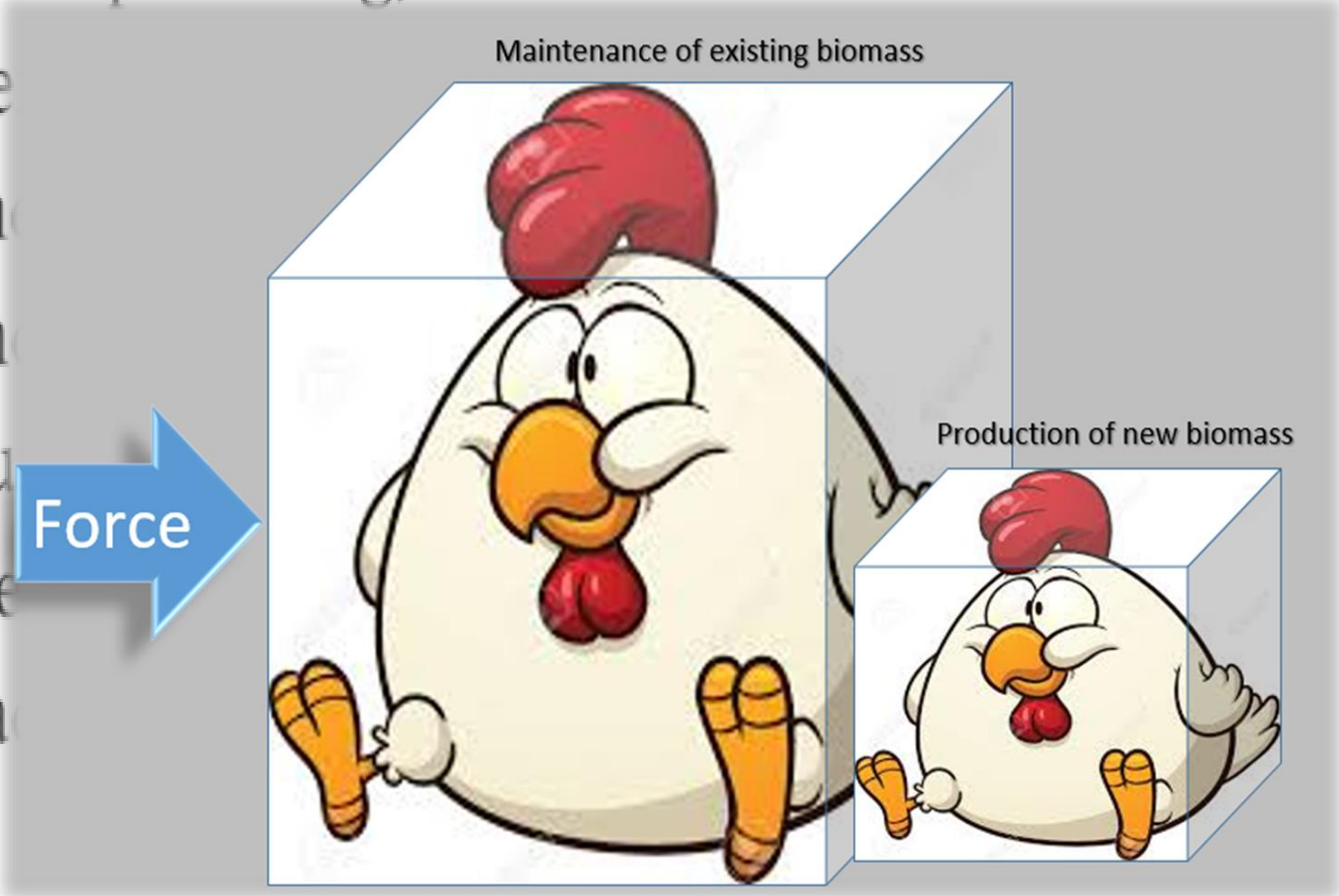
Law (entropy always wins), the Prin

increase) always wins in the long ru

envisaged as a "struggle" between the

least action. The only way that least a

done (an increase in power).



Principle Of Minimal Action And Kinetic Energy https://www.youtube.com/watch?v=AfsZiHEcoxk

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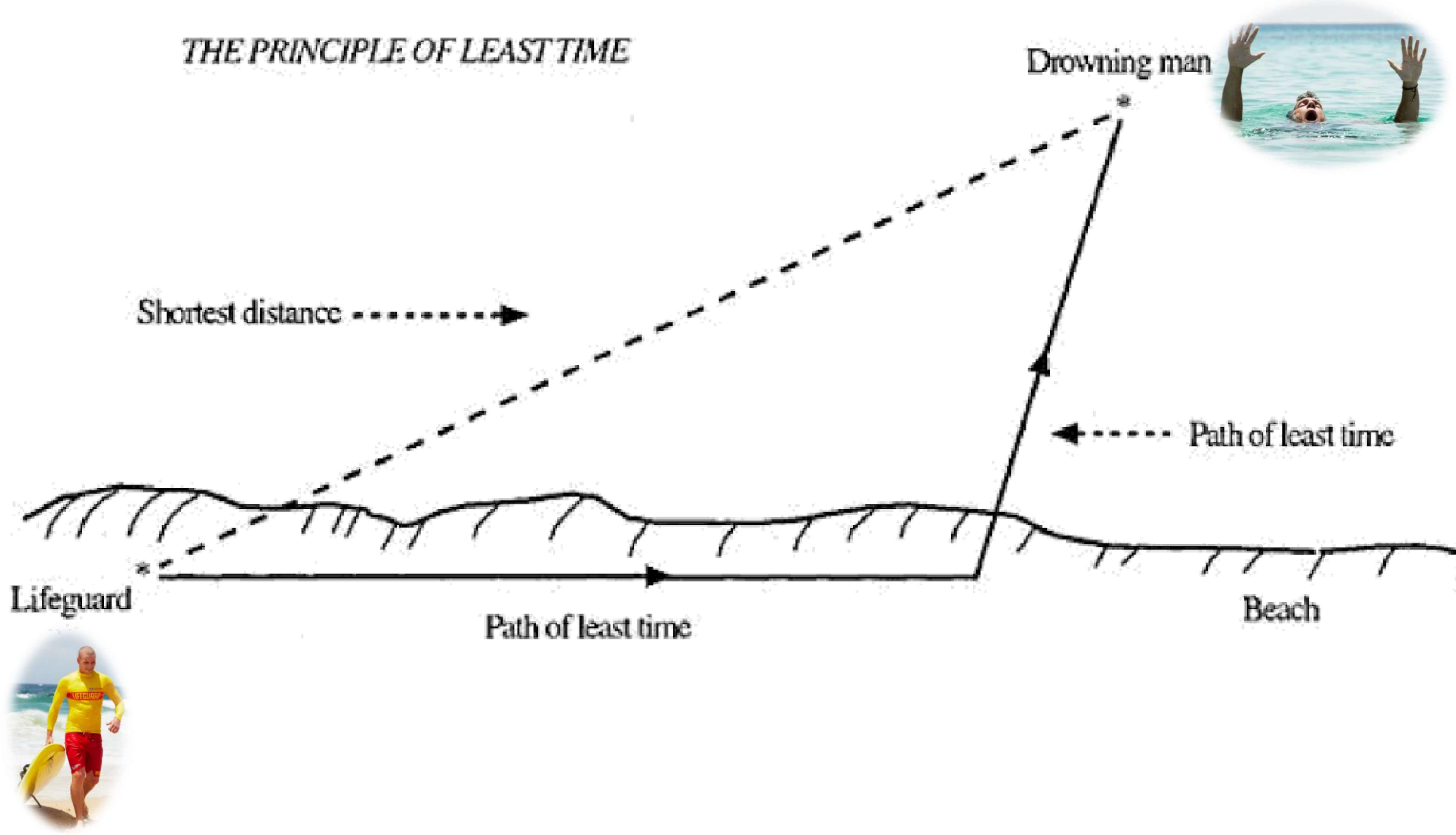
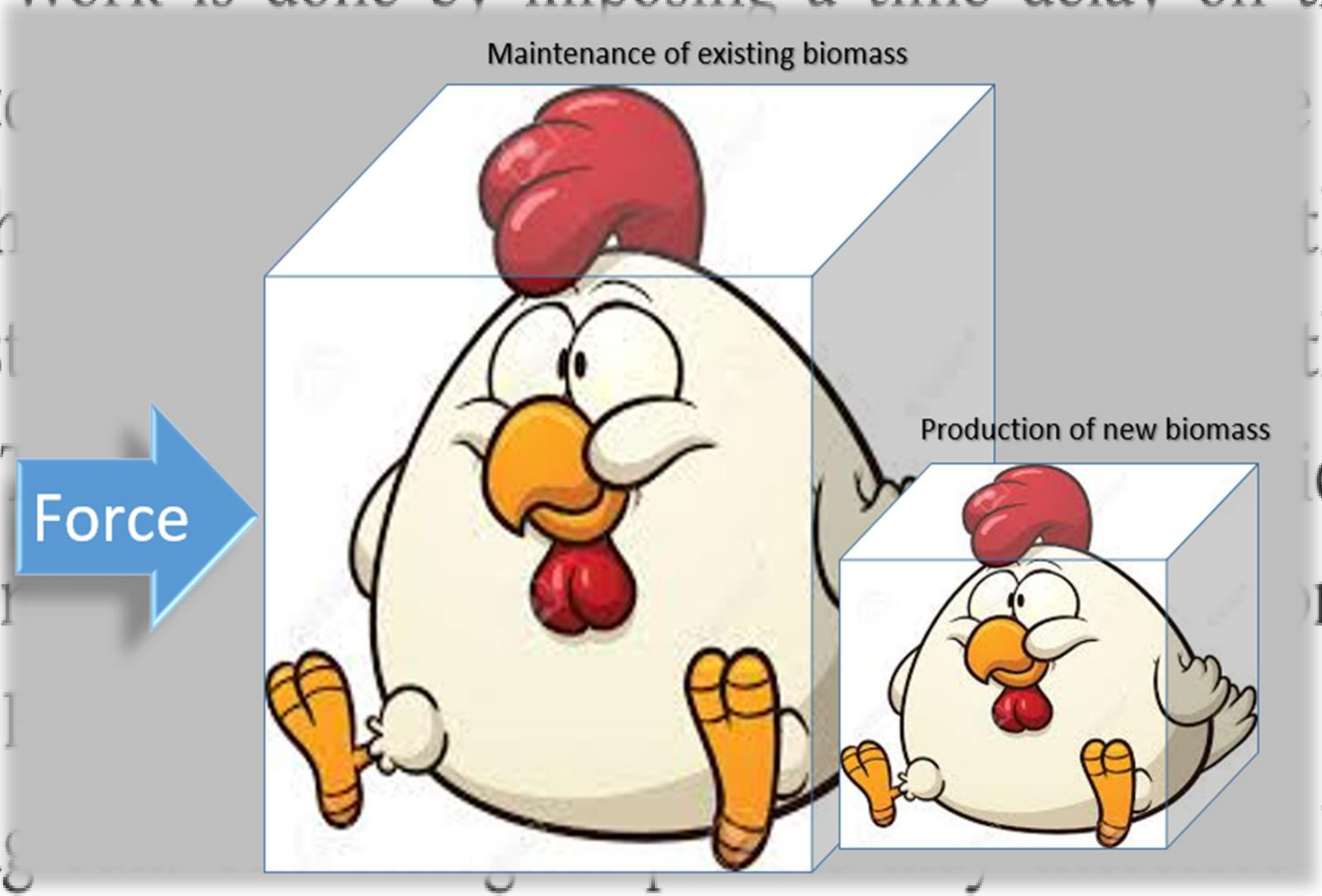
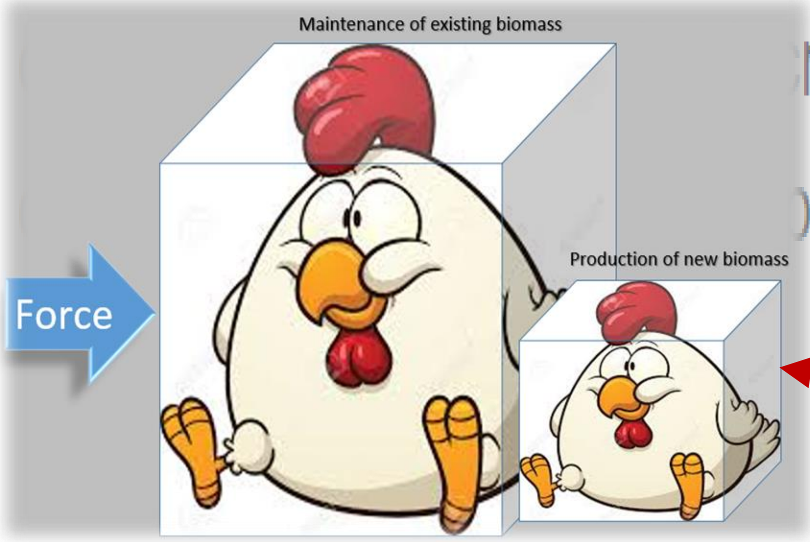

THE PRINCIPLE OF LEAST TIME
Drowning man
Shortest distance
Path of least time
Lifeguard
Path of least time
Beach
LIFEGUARD

rapidly as the constraints allow. Work is done by imposing a time delay on the passage of energy from one state t[...] in potential energy in some part of th[...] the least for the conditions and cons[...] the more efficiently it is performed. [...] on must dominate system behavior i[...] nd Law (entropy always wins), the [...] to increase) always wins in the long [...] be envisaged as a "struggle" between the principle of least work and the principle of least action. The only way that least action can win is through an increase in work done (an increase in power).



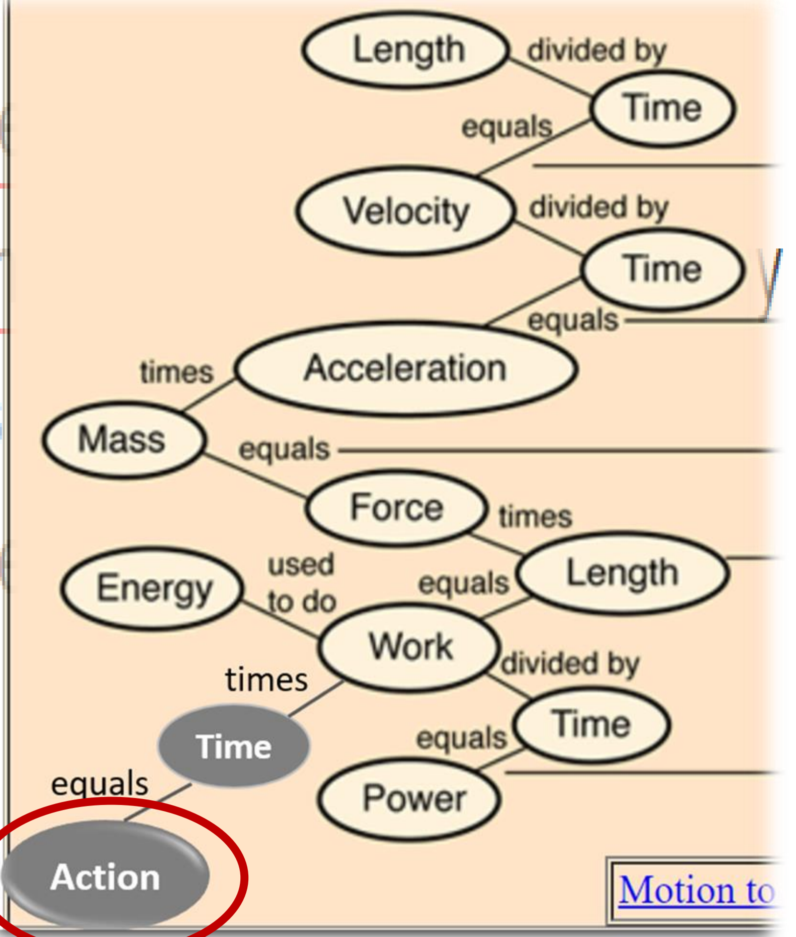
Organisms may be characterized by their ability to capture and store

dimensions of action seem appropriate to the measurement of system

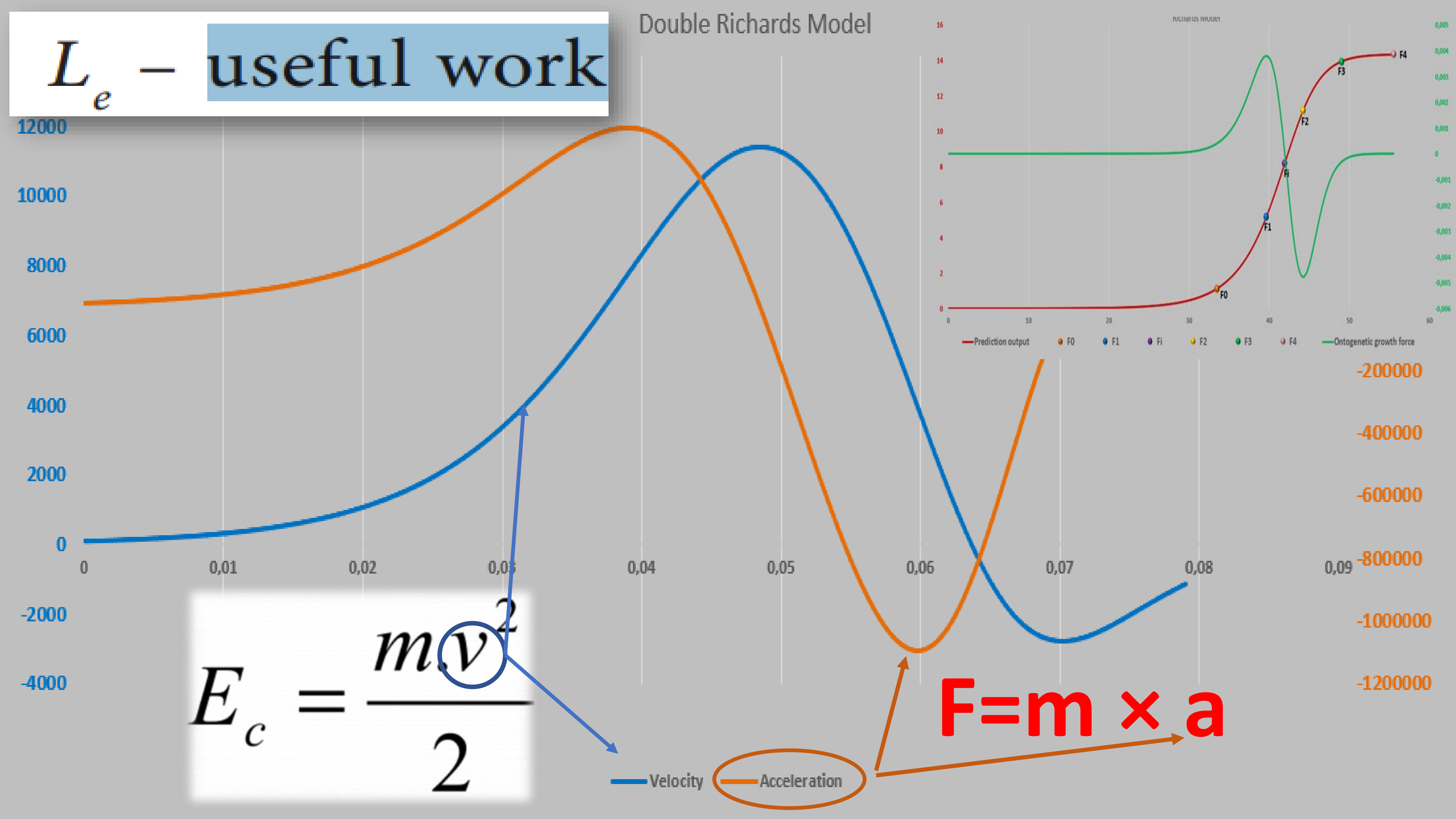


rease, organisms may be regarded as

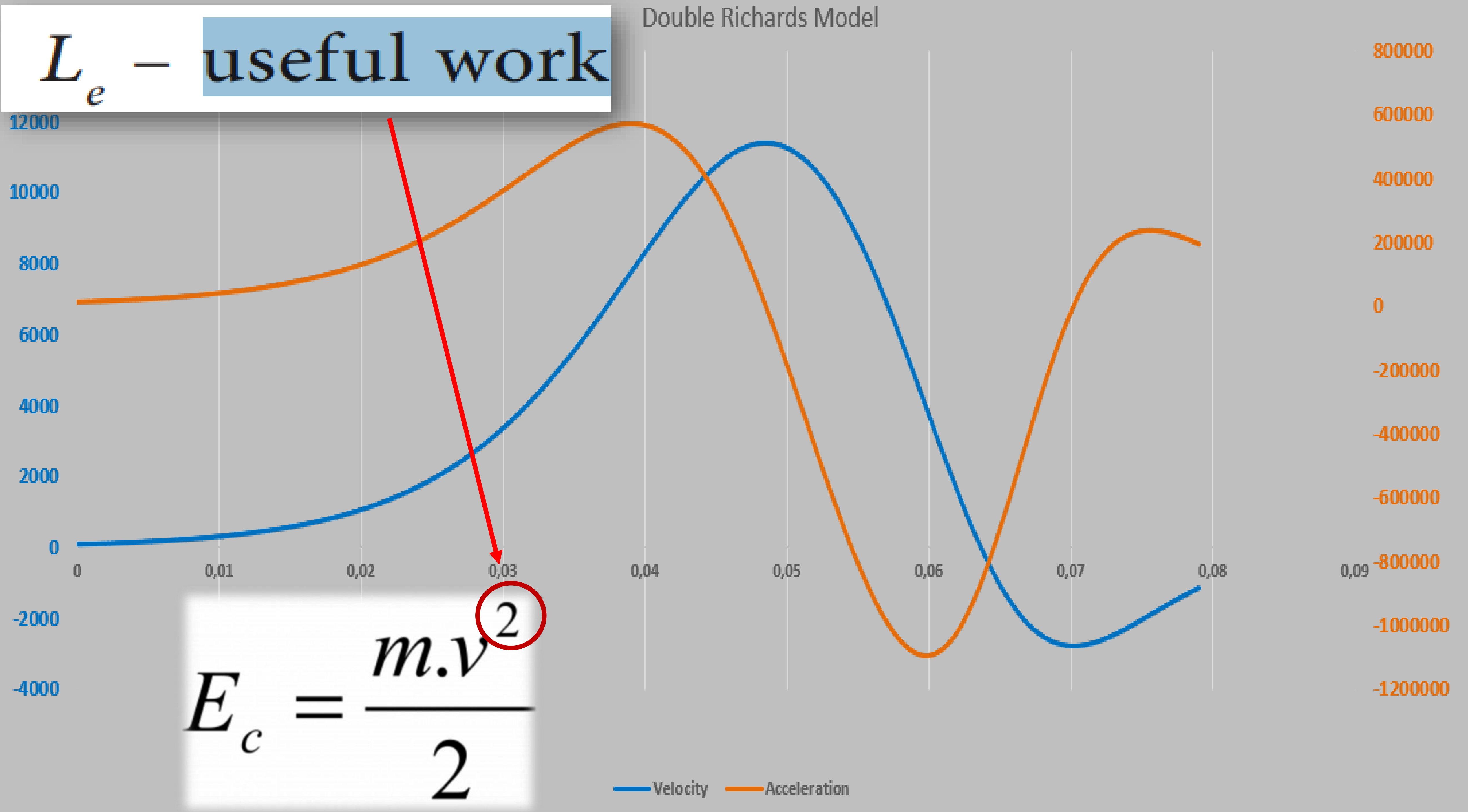
physical systems, that is, toward a stat



system maintenance. The trend to most action (energy x time) expresses the innate capacity of organisms to acquire, concentrate, and conserve energy. Thus, in an ecosystem, the capacity of the


L_e – useful work
Double Richards Model
12000
10000
8000
6000
4000
2000
0
-2000
-4000
0
0,01
0,02
0,03
0,04
0,05
0,06
0,07
0,08
0,09
-200000
-400000
-600000
-800000
-1000000
-1200000
Velocity
Acceleration
$E_c = \frac{mv^2}{2}$
F=m × a
Prediction output
F0
F1
Fi
F2
F3
F4
Ontogenetic growth force

L_e – useful work



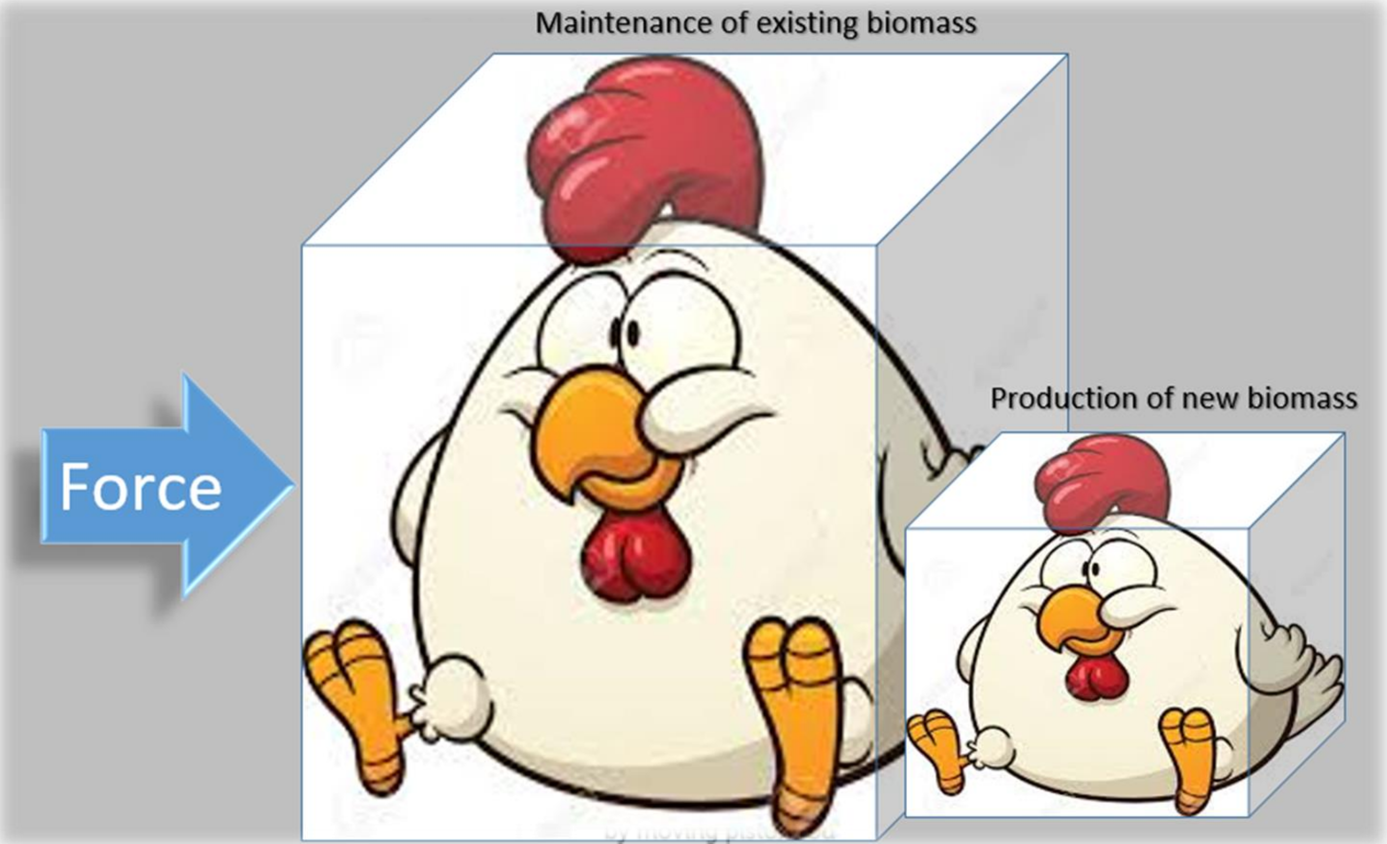
$$E_c = \frac{m.v^2}{2}$$

We can say that the Chemical Energy of the fuel is converted into Thermal Energy during the gasoline or diesel explosion. This released Thermal Energy causes the motor to tighten the piston of the engine, producing movement and, consequently, Kinetic Energy. The more Thermal Energy an engine can turn into Kinetic Energy, ***the more economical and efficient*** **it is.**

L_e – useful work

$$E_c = \frac{m.v^2}{2}$$

Internal Combustion Engine



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April, 2019

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New Gompertz

5-parameter Richards Model

Richards Model

Double Logistic curve

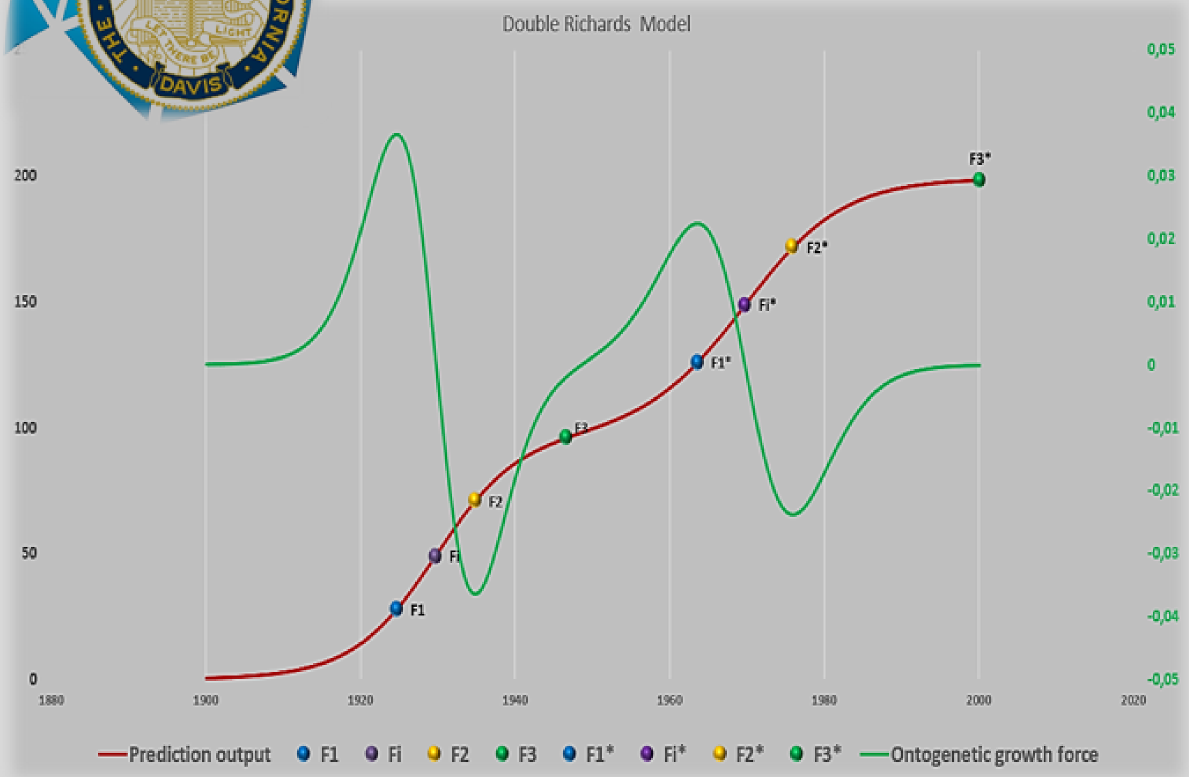
Weibull Model

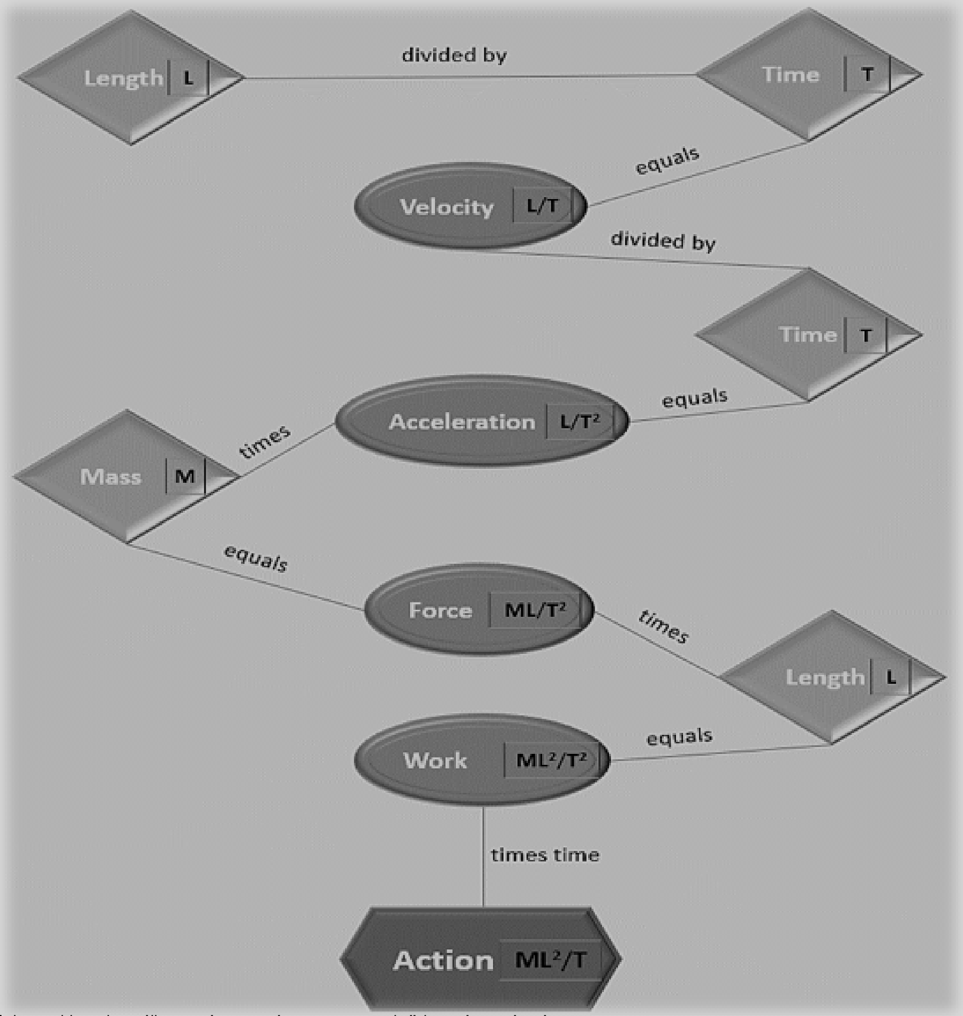
Double Richards curve

5-parameter General Model

Triple Logistic curve

5-parameter Logistic Model





Adapted from http://hyperphysics.phy-astr.gsu.edu/hbase/units.html

Practical Program for Forces Modeling

The PPFM worksheet adjusts up to 1000 data for multiple models by the Excel Solver tool

A planilha PPFM ajusta até 1000 dados para vários modelos pela ferramenta Solver do Excel

Manoel Garcia Neto m.garcia@unesp.br
Ermias Kebreab ekebreab@ucdavis.edu
Max José de Araujo Faria Júnior max.faria@unesp.br

Programa Prático para Modelagem de Forças

Phormia regina - Black Blow Fly - *Phormia regina*

Millhaven, Lennox and Addington, Ontario, Canada
June 9, 2013
Size: 7-8 mm

https://academic.oup.com/jme/article/50/2/252/852494

Laboratory Development and Field Validation of *Phormia regina* (Diptera: Calliphoridae)

Carolina Núñez-Vázquez ✉, Jeffery K. Tomberlin, Mario Cantú-Sifuentes, Oswaldo García-Martínez

Journal of Medical Entomology, Volume 50, Issue 2, 1 March 2013, Pages 252–260,
https://doi.org/10.1603/ME12114

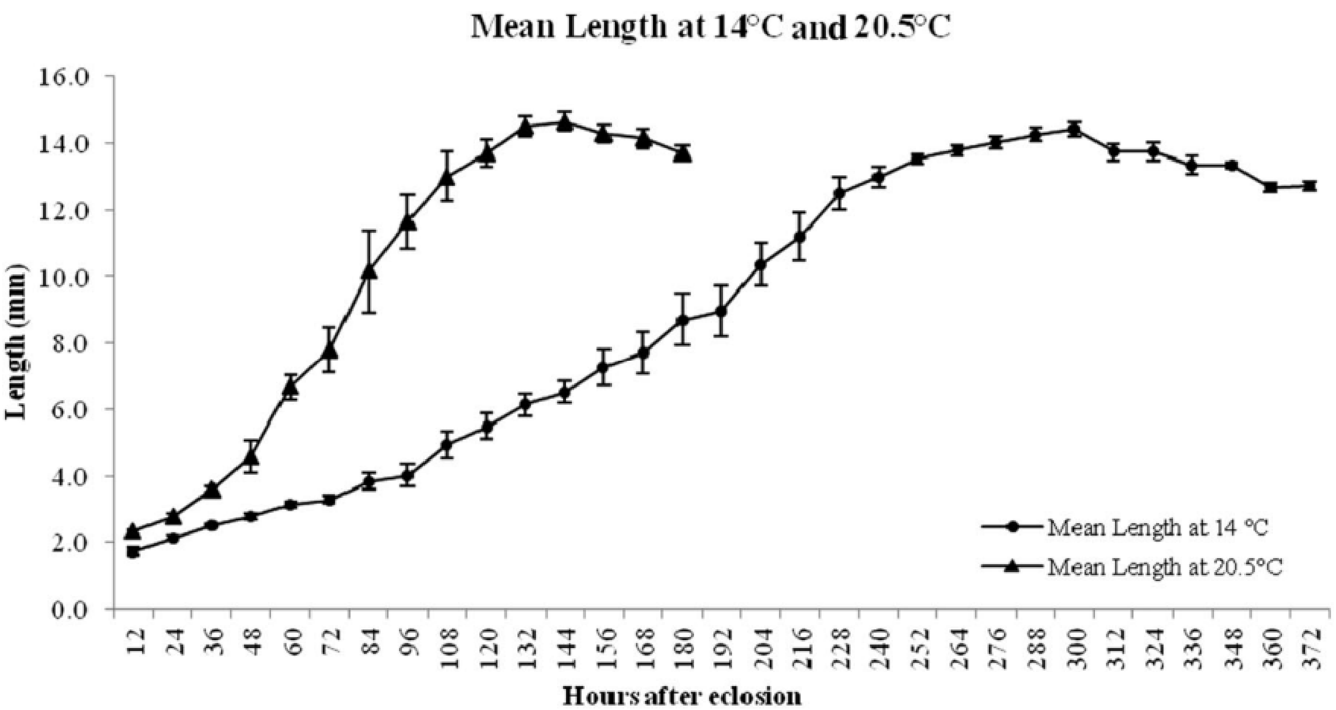
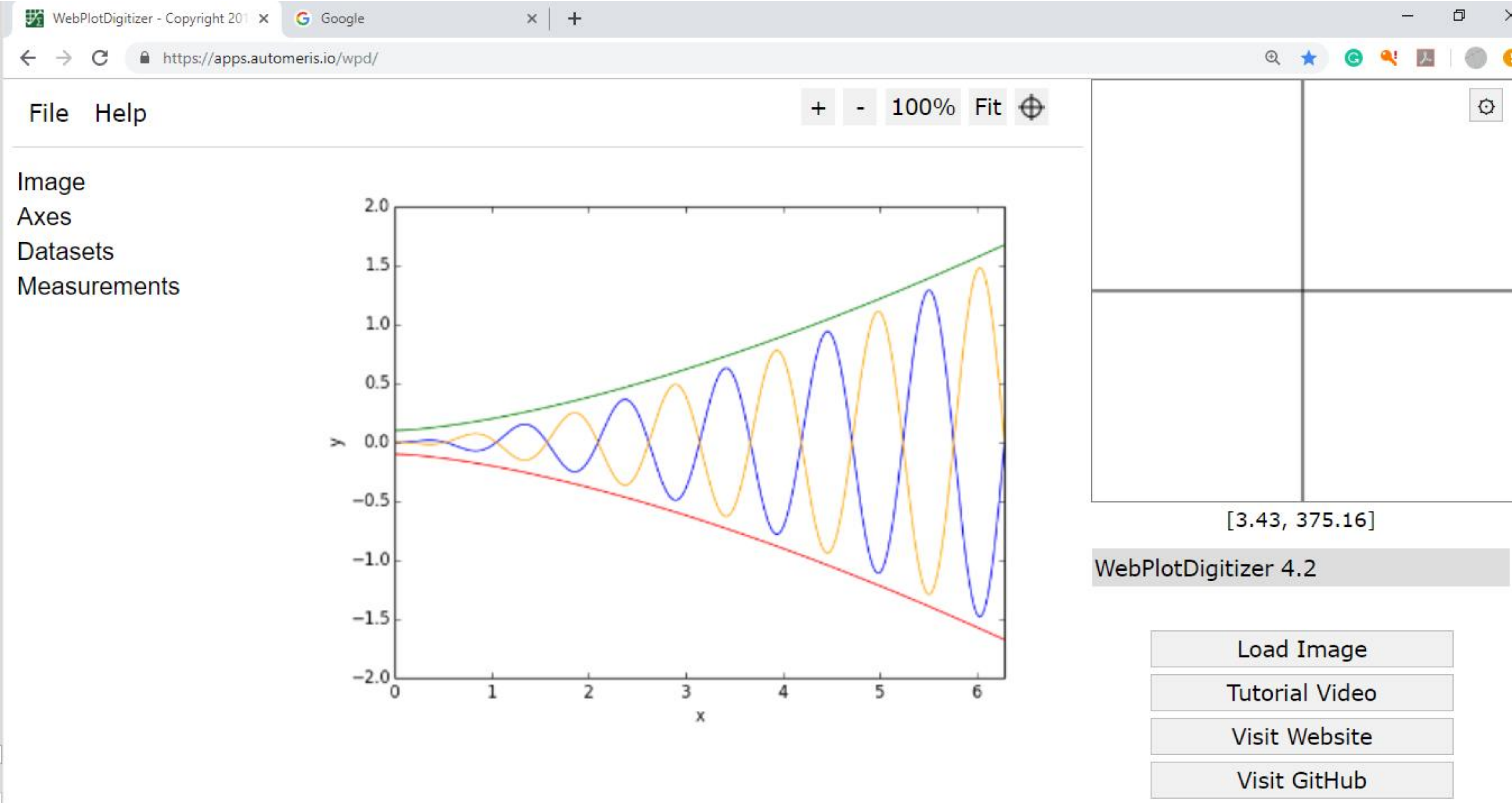


Fig. 1. Mean length development of larval instars of *Phormia regina* reared at cyclic temperatures of 14.0°C (±6°C) and 20.5°C (±6°C). The dark line connects the mean length data.


WebPlotDigitizer - Copyright 20
Google
https://apps.automeris.io/wpd/
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Fit
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Datasets
Measurements
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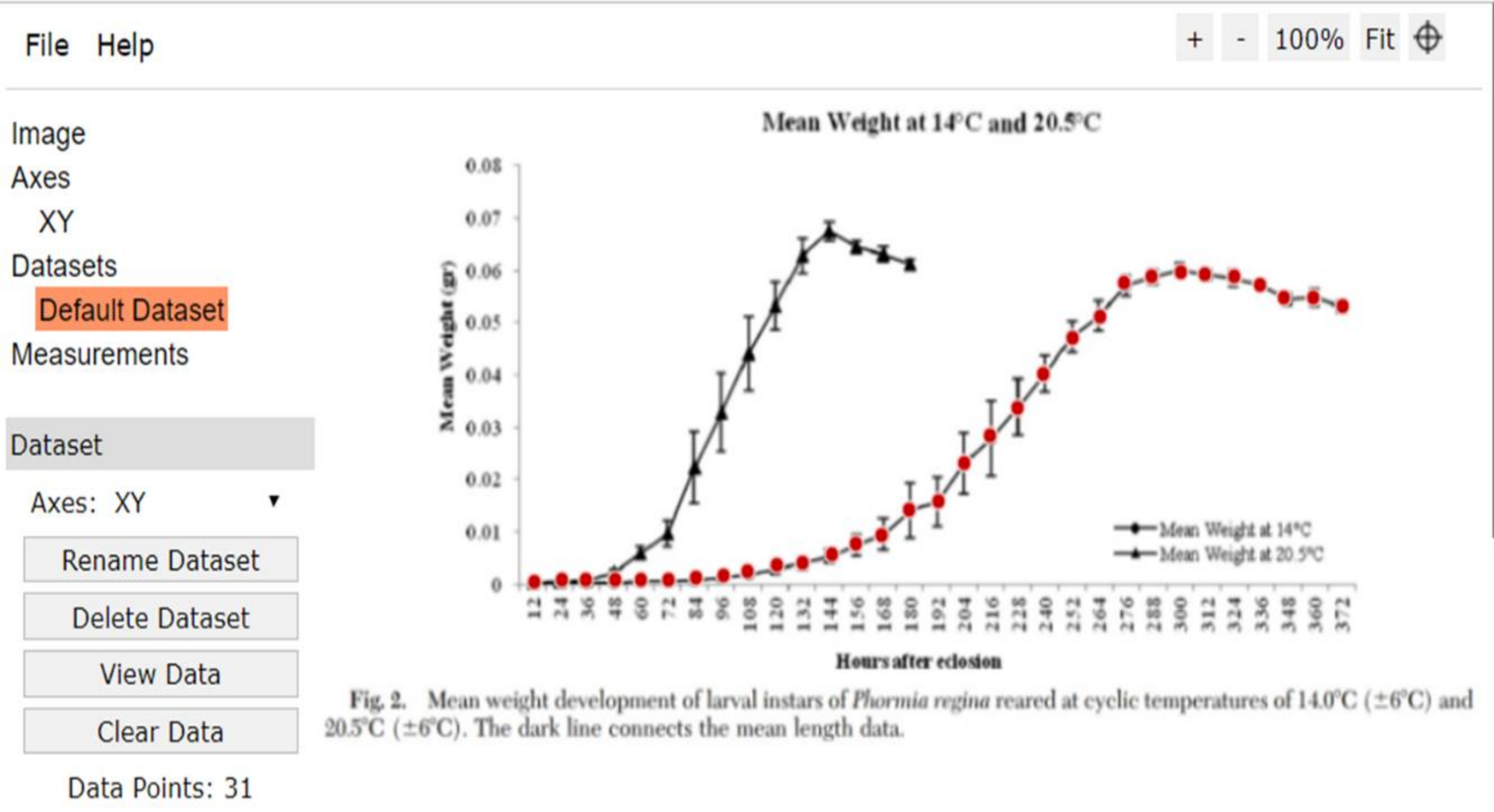
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
y
0
1
2
3
4
5
6
x
[3.43, 375.16]
WebPlotDigitizer 4.2
Load Image
Tutorial Video
Visit Website
Visit GitHub


File
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Fit
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XY
Datasets
Default Dataset
Measurements
Dataset
Axes: XY
Rename Dataset
Delete Dataset
View Data
Clear Data
Data Points: 31
Mean Weight at 14°C and 20.5°C
Mean Weight (gr)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
12 24 36 48 60 72 84 96 108 120 132 144 156 168 180 192 204 216 228 240 252 264 276 288 300 312 324 336 348 360 372
Hours after eclosion
Mean Weight at 14°C
Mean Weight at 20.5°C
Fig. 2. Mean weight development of larval instars of *Phormia regina* reared at cyclic temperatures of 14.0°C (±6°C) and 20.5°C (±6°C). The dark line connects the mean length data.

Fitting the Double Richards Model to Response D

AIC$_c$= 84,442 BIC= 89,6107

Clear Data Range | HOME | Save

Point	*Input (x)*	*Output (y)*	*Residuals*	*Expected*	*Qm*
1	0	0,033872	-0,6609	0,6948	0,629
2	0,0026915	1,985727	1,0096	0,9761	1,044
3	0,0050234	2,040769	0,7305	1,3102	0,407
4	0,0078934	2,108512	0,2270	1,8815	0,027
5	0,0104046	2,167788	-0,4131	2,5808	0,066
6	0,0130952	2,231297	-1,3868	3,6181	0,532
7	0,0157868	4,183153	-0,8840	5,0672	0,154
8	0,0184783	6,135009	-0,9502	7,0852	0,127
9	0,020812	9,966743	0,5081	9,4586	0,027
10	0,0236847	15,69953	2,2424	13,457	0,374
11	0,0261968	17,64715	-0,6013	18,248	0,02
12	0,0290705	25,26828	-0,4339	25,702	0,007
13	0,0314069	34,76505	1,0192	33,746	0,031
14	0,0339218	42,37771	-2,4932	44,871	0,139
15	0,0366233	65,10138	4,8961	60,205	0,398
16	0,0394969	72,7225	-8,1445	80,867	0,82
17	0,0420246	106,772	3,8877	102,88	0,147
18	0,0445476	131,3798	3,2521	128,13	0,083
19	0,0472501	155,9918	-1,8082	157,8	0,021
20	0,0497759	186,2646	-0,2135	186,48	2E-04
21	0,0526614	218,4343	0,5411	217,89	0,001
22	0,0553611	237,3812	-6,0107	243,39	0,148
23	0,0577075	267,6498	6,9639	260,69	0,186
24	0,0604009	273,3784	-0,1920	273,57	1E-04
25	0,0632727	277,2228	-1,5305	278,75	0,008
26	0,0656036	275,3895	-2,0026	277,39	0,014
27	0,0684727	273,5689	2,2467	271,32	0,019
28	0,0709803	266,0748	1,6086	264,47	0,01
29	0,0733067	254,7997	-3,5957	258,4	0,05
30	0,0761767	254,8675	2,4990	252,37	0,025
31	0,079043	247,3818	-0,8388	248,22	0,003
32					
33					
34					
35					
36					
37					
38					
39					
40					
41					
42					
43					
44					
45					
46					
47					
48					

Sample Statistics

Min Input	0,0000	Min Output	0,03
Max Input	0,0790	Max Output	277,22

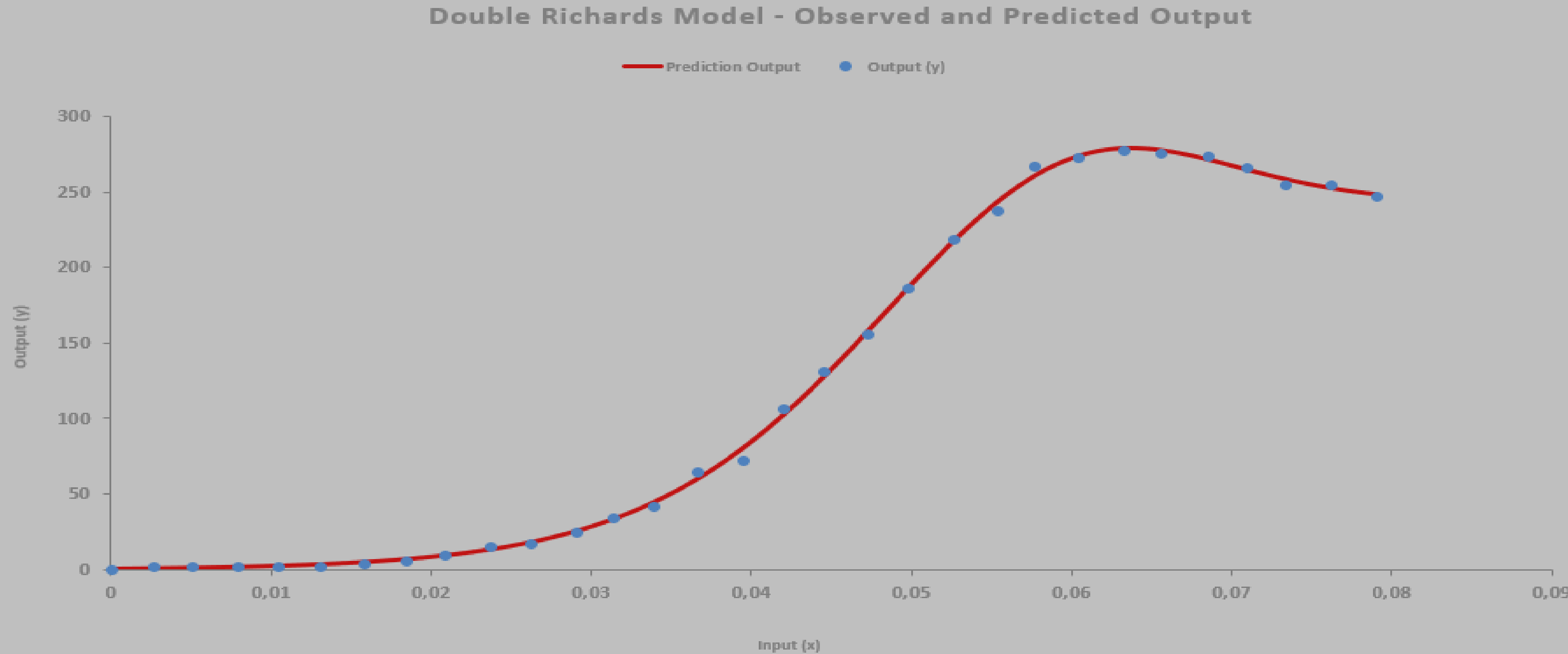
Regression

a	b	c	d	a'	b'	c'	d'	*SSE*
384,6201408	1,993834966	125,8511259	0,049914055	243,2804858	1,778597081	176,1368371	0,066675711	257,0418
-5,300606967	0,988596297	121,1010381	0,0417145	219,154985	1,662412009	142,4116033	0,064795768	*Lower 95% Confidence Levels*
774,5408885	2,999073635	130,6012137	0,058113611	267,4059866	1,894782153	209,8620709	0,068555654	*Upper 95% Confidence Levels*
198,939157	0,512876872	2,4235142	0,004183447	12,30892898	0,059278098	17,20675194	0,000959155	*Standard Errors*
1,933355638	3,887550939	51,92918857	11,93132343	19,76455353	30,00428728	10,2364954	69,51507839	*t-Statistics*
0,065593952	0,000743473	P<0.0001	P<0.0001	P<0.0001	P<0.0001	P<0.0001	P<0.0001	*p-values*
Goodness of Fit (R^2_{adj}) 99,934%		**Qm = 5,51798590482769**					**Critical Xi^2 =**	*36,4150285*

Regression models with Qm>critical Xi^2, indicating inadequate fits, are highlighted in red

Functional Form

$$y = a\left[1+(b-1)e^{-c(x-d)}\right]^{1/(1-b)} + (a'-a)\left[1+(b'-1)e^{-c'(x-d')}\right]^{1/(1-b')}$$



1. Copy data
2. View the c
a' and d
3. Guess val
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4. Press the
Fit Double
5. Solver will
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speed.
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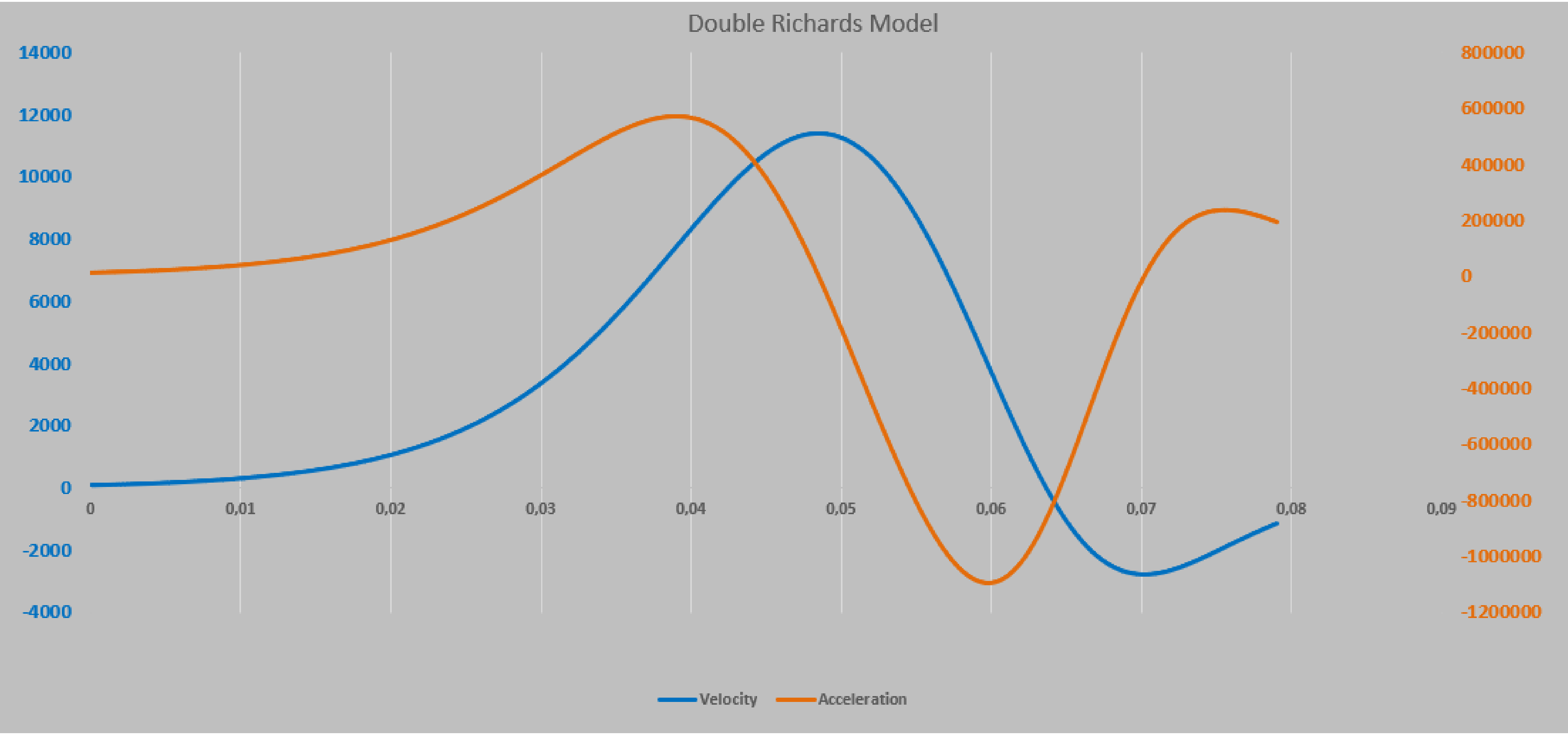
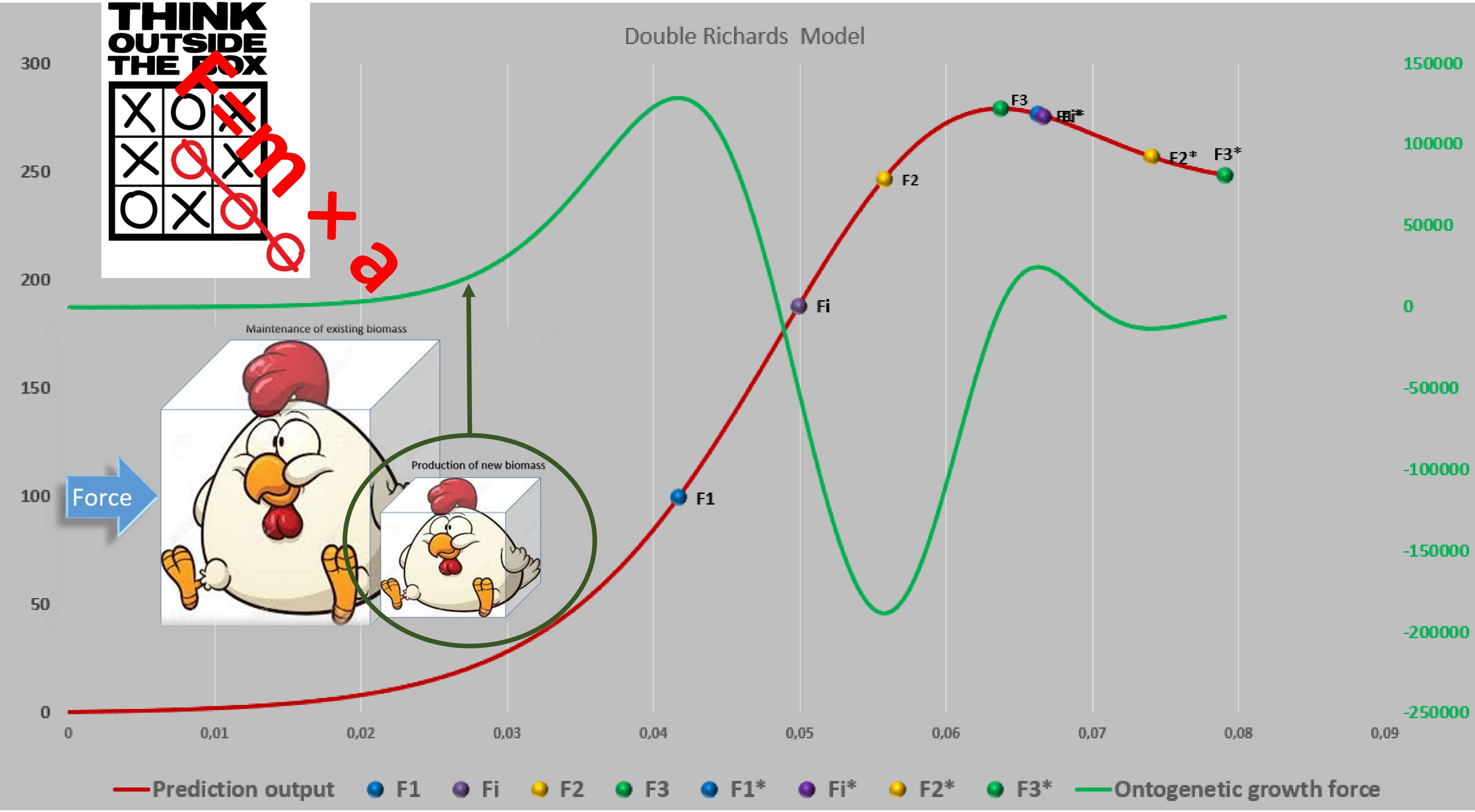
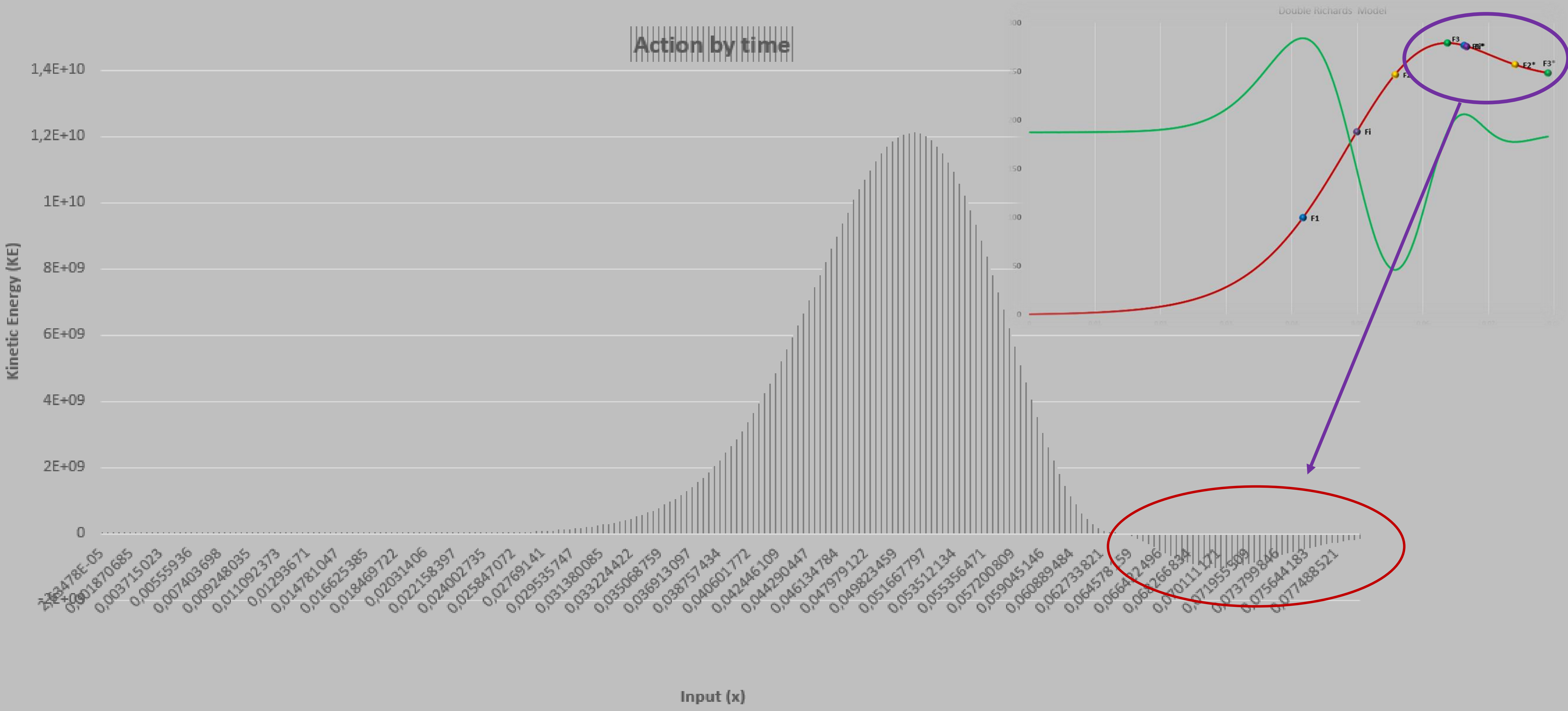


Double Richards Model
14000
12000
10000
8000
6000
4000
2000
0
-2000
-4000
800000
600000
400000
200000
0
-200000
-400000
-600000
-800000
-1000000
-1200000
0
0,01
0,02
0,03
0,04
0,05
0,06
0,07
0,08
0,09
Velocity
Acceleration



Double Richards Model
THINK OUTSIDE THE BOX
F=m×a
Maintenance of existing biomass
Production of new biomass
Force
F1
Fi
F2
F3
Fi*
F2*
F3*
300
250
200
150
100
50
0
150000
100000
50000
0
-50000
-100000
-150000
-200000
-250000
0
0,01
0,02
0,03
0,04
0,05
0,06
0,07
0,08
0,09
Prediction output
F1
Fi
F2
F3
F1*
Fi*
F2*
F3*
Ontogenetic growth force



Kinetic Energy (KE)			Time	Weight
$KE_{maximum}$ =	#########	1,2118E+10	0,051	199,372

By Time

ACTION =	###########	6,2156E+12	**0,079**	248,191

Theory of growth based on first principles of energy conservation and allocation:

$$KE=m*v^2/2$$

KE= Kinetic Energy

m=total biomass

v=velocity

Power tells you how fast a job is done (J / s). The action, on the other hand, clarifies how

SENSORS

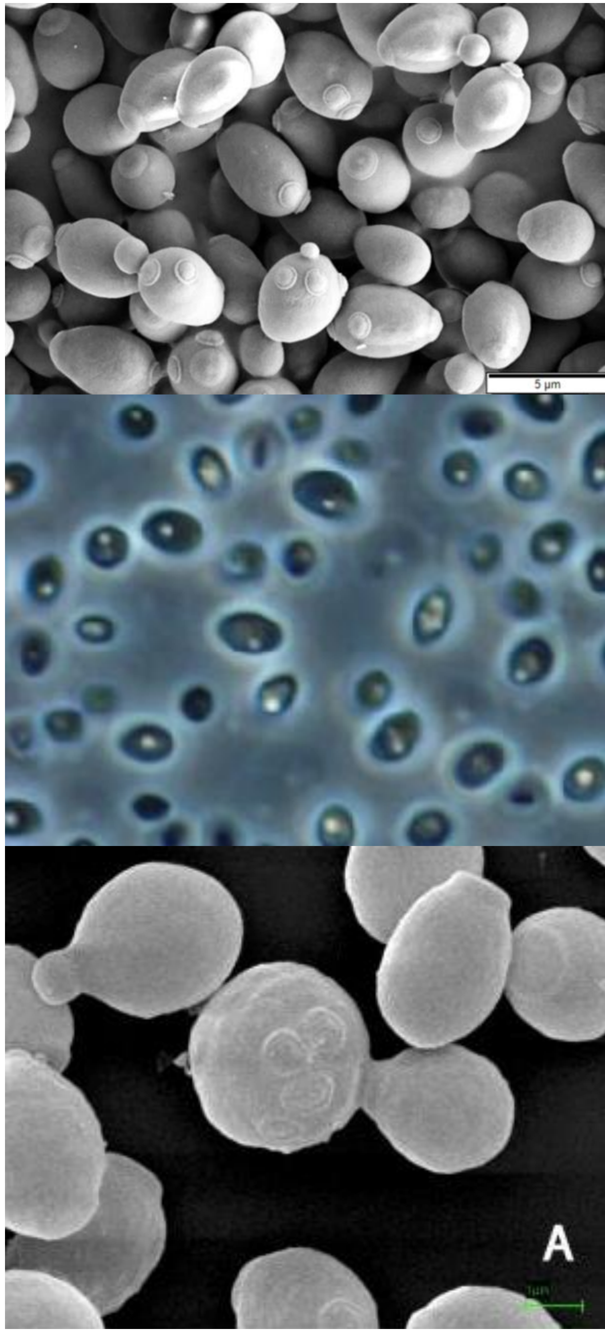
Consistency of the Mediated Electrochemical Method and the Fluorescence Method in Monitoring the Catabolic Activities of Yeasts

Jinsheng Zhao,[1] Zhong Wang,[2] Chonggang Fu,[1] Jifeng Liu,[1] and Qingpeng He[1]

[1]Department of Chemistry and Chemical Engineering, Liaocheng University, Liaocheng, P. R. China

[2]School of Medicine, Ehime University, Toon, Japan

Abstract: The mediated electrochemical method and the intrinsic NADH fluorescence method were employed in evaluating the catabolic activities of three yeasts. The responses from the menadione/ferricyanide system were 70.00 ± 2.25 nA, 61.39 ± 1.76 nA, and 57.18 ± 1.51 nA, respectively, for *Saccharomyces cerevisiae*, *Pachysolen tannophilus*, and *Pichia stipitis*. The NADH fluorescence intensities were 1638 ± 25.46 FI, 1039 ± 18.67 FI, and 963.4 ± 15.78 FI, respectively,for *S. cerevisiae*, *P. tannophilus*, and *P. stipitis*. It was evident that there is a positive relationship between the mediated electrochemical method and the intrinsic NADH fluorescence method in cellular metabolic activity assays.



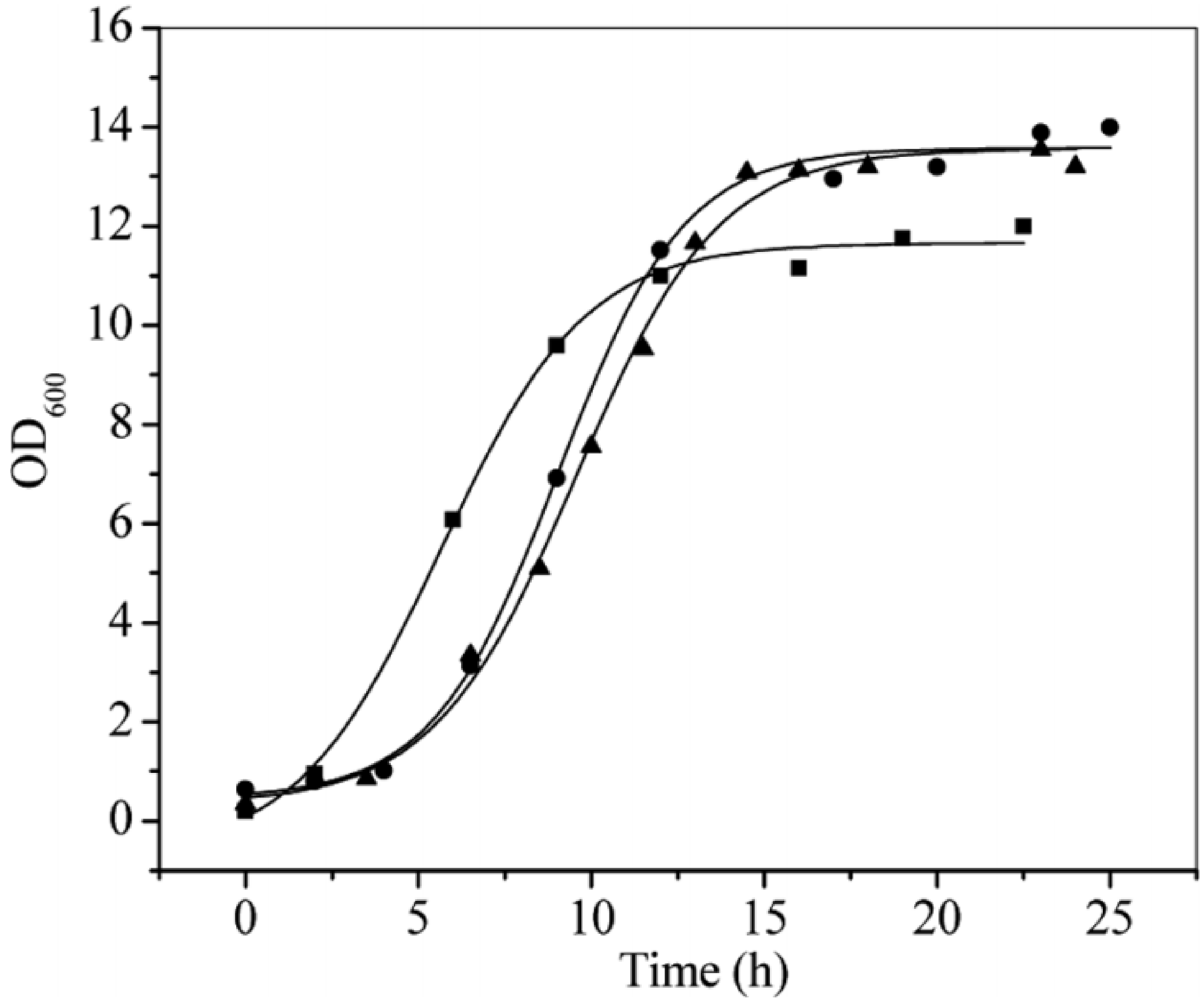
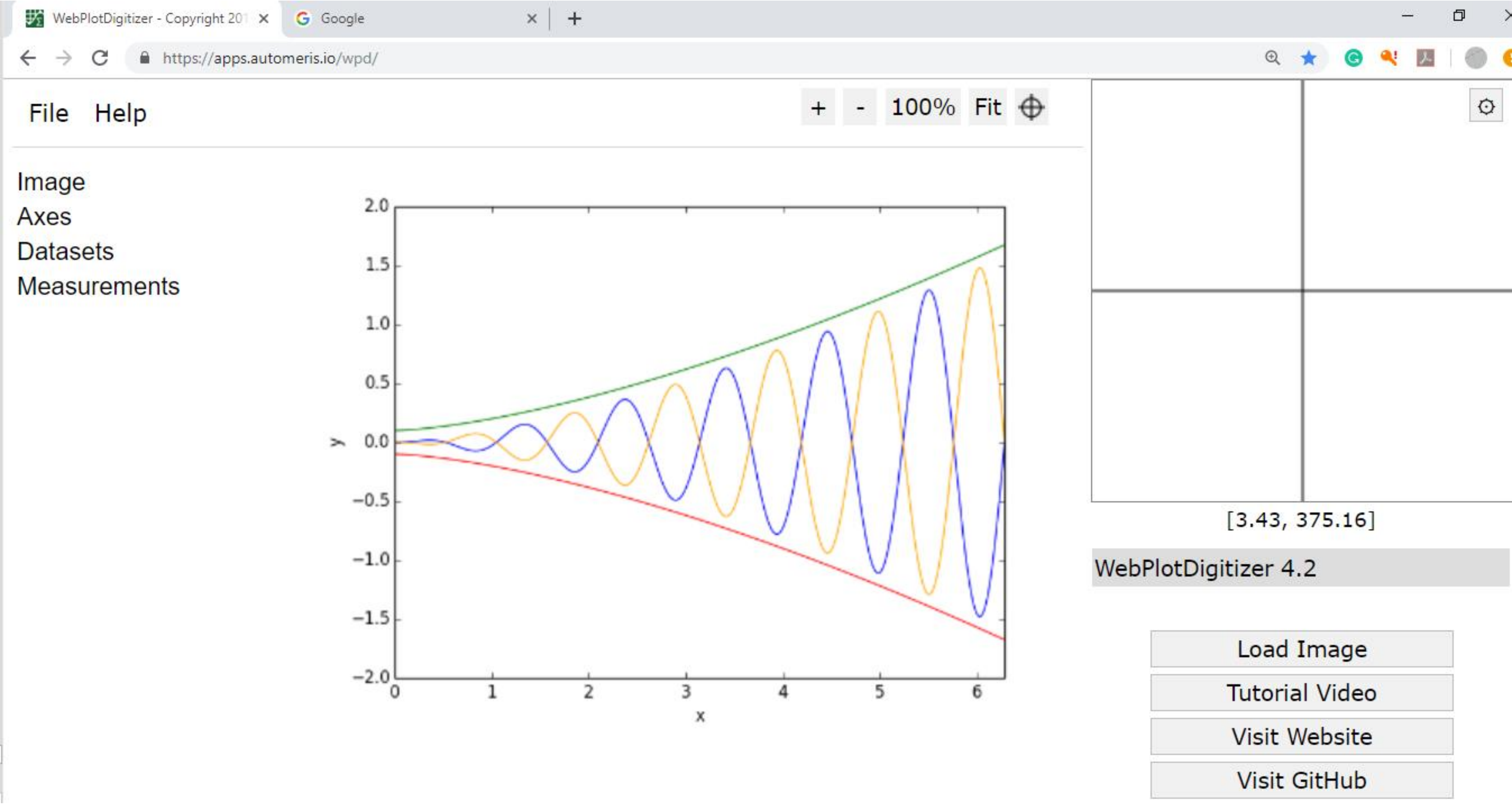


Figure 2. Growth curves for three yeasts obtained by optical density at 600 nm: *S. cerevisiae* (■), *P. tannophilus* (●), and *P. stipitis* (▲). The incubation conditions are stated in the text.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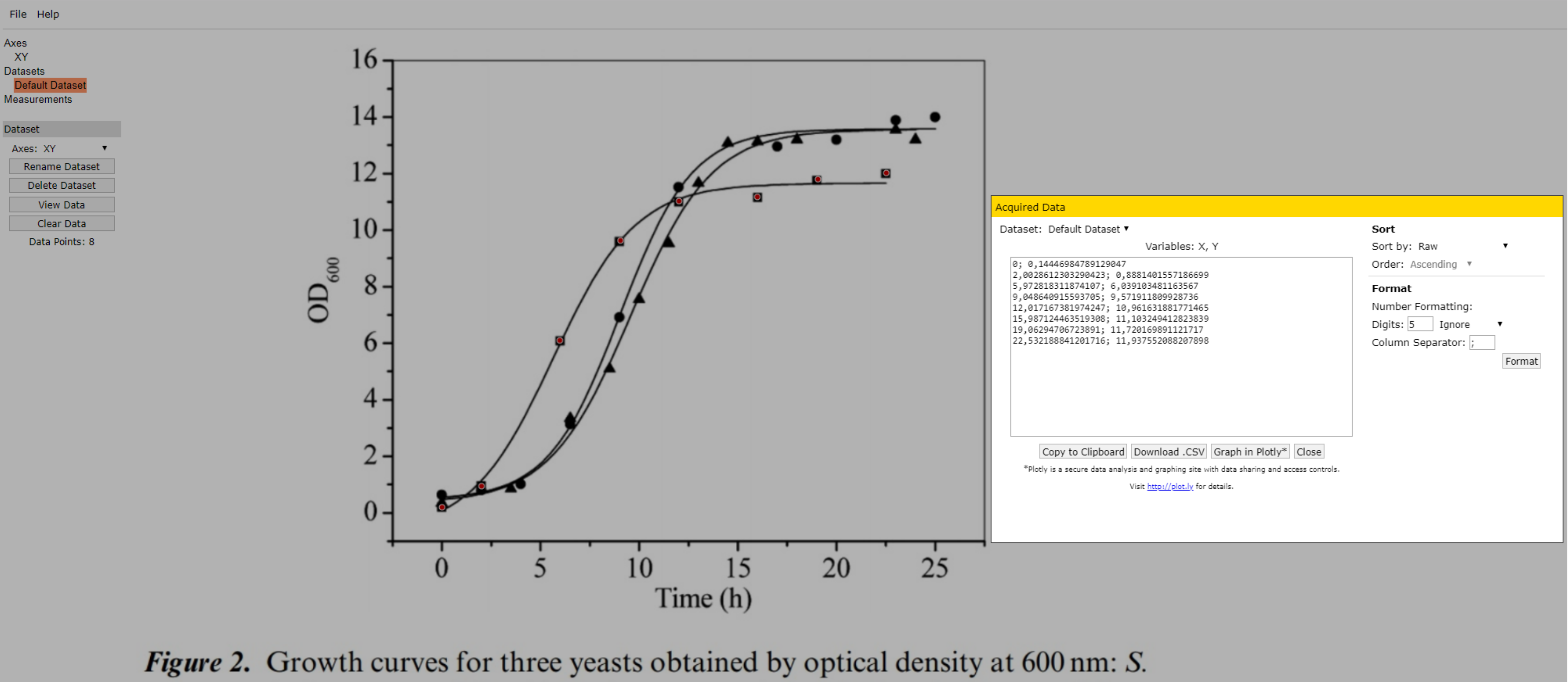
−1.0
−1.5
−2.0
y
0
1
2
3
4
5
6
x
[3.43, 375.16]
WebPlotDigitizer 4.2
Load Image
Tutorial Video
Visit Website
Visit GitHub


File Help
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XY
Datasets
Default Dataset
Measurements
Dataset
Axes: XY
Rename Dataset
Delete Dataset
View Data
Clear Data
Data Points: 8
16
14
12
10
8
6
4
2
0
OD_{600}
0
5
10
15
20
25
Time (h)
Acquired Data
Dataset: Default Dataset
Variables: X, Y
0; 0,14446984789129047
2,0028612303290423; 0,8881401557186699
5,972818311874107; 6,039103481163567
9,048640915593705; 9,571911809928736
12,017167381974247; 10,961631881771465
15,987124463519308; 11,103249412823839
19,06294706723891; 11,720169891121717
22,532188841201716; 11,937552088207898
Sort
Sort by: Raw
Order: Ascending
Format
Number Formatting:
Digits: 5 Ignore
Column Separator: ;
Format
Copy to Clipboard
Download .CSV
Graph in Plotly*
Close
*Plotly is a secure data analysis and graphing site with data sharing and access controls.
Visit http://plot.ly for details.
Figure 2. Growth curves for three yeasts obtained by optical density at 600 nm: *S.*

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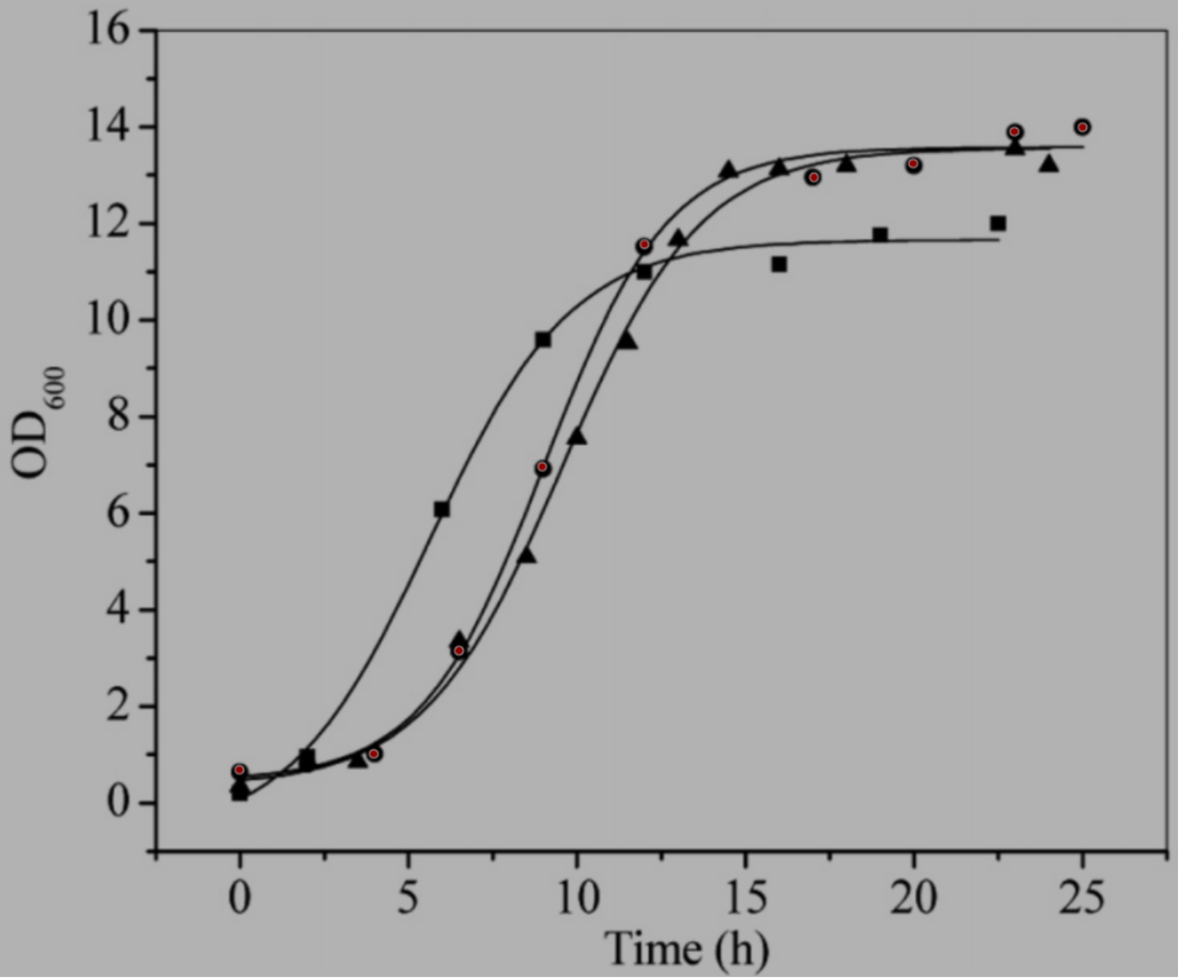
https://apps.automeris.io/wpd/

File Help

Axes
XY
Datasets
Default Dataset
Measurements

Dataset
Axes: XY
Rename Dataset
Delete Dataset
View Data
Clear Data
Data Points: 9



Acquired Data

Dataset: Default Dataset

Variables: X, Y

```
-0,0033085770506637857; 0,6589292399850244
3,978346233881574; 0,9859977536503202
6,502572853995979; 3,1215135869328634
8,9602796618286; 6,932019189746896
11,985320366033108; 11,535413093258342
17,007870930667902; 12,919415252540205
19,94662742810375; 13,203325990614092
22,947855084325187; 13,861837305076927
24,970440476086825; 13,948208579662701
```

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*Plotly is a secure data analysis and graphing site with data sharing and access controls.

Visit http://plot.ly for details.

Sort

Sort by: Raw

Order: Ascending

Format

Number Formatting:

Digits: 5 Ignore

Column Separator: ;

Format

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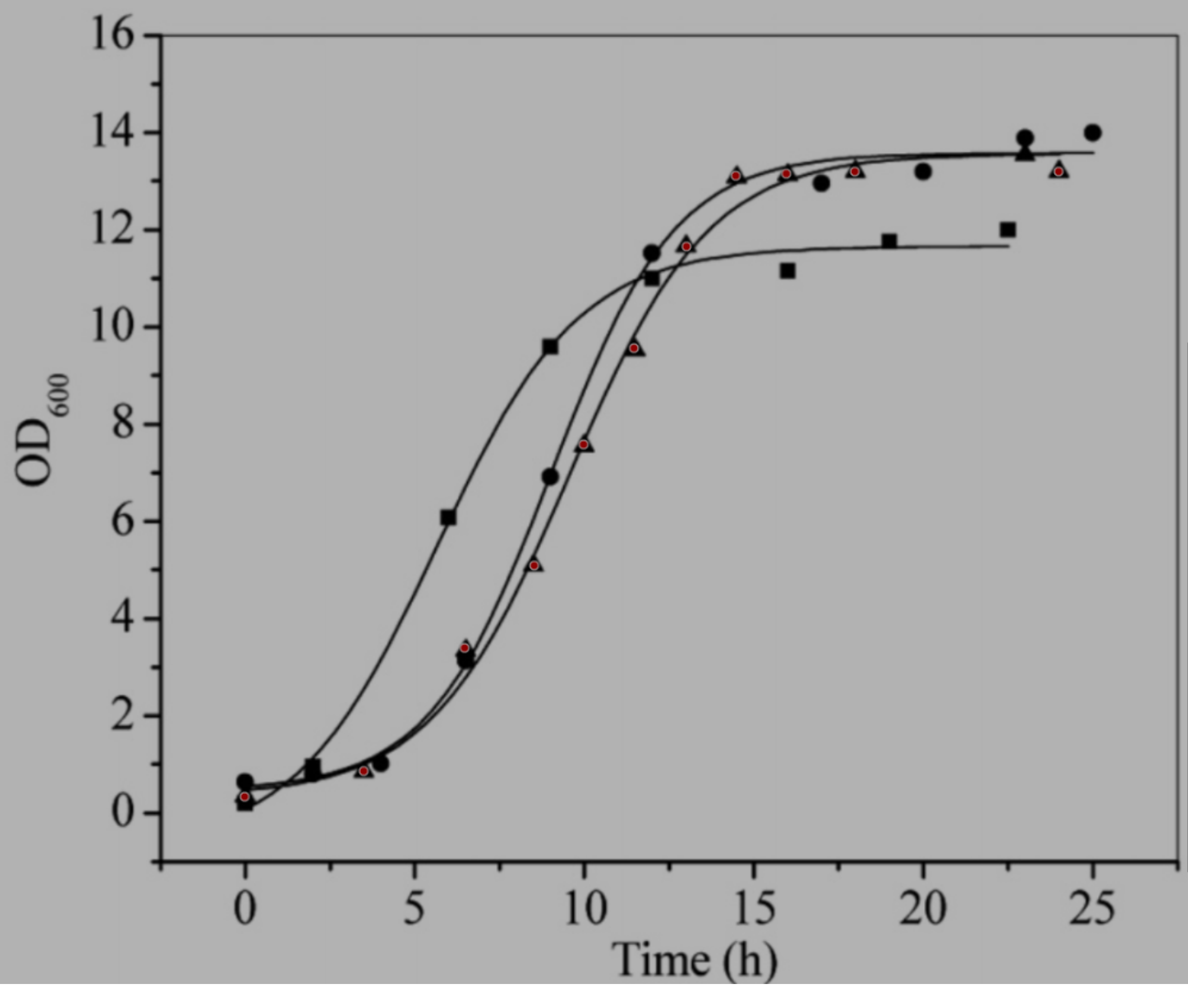
https://apps.automeris.io/wpd/

File Help

Axes
XY
Datasets
Default Dataset
Measurements

Dataset
Axes: XY
Rename Dataset
Delete Dataset
View Data
Clear Data
Data Points: 11



Acquired Data

Dataset: Default Dataset

Variables: X, Y

```
-0,0025684916598045504; 0,3107683359830844
3,5045980354086126; 0,8427856728664551
6,470509362369768; 3,379835512052752
8,521515253357759; 5,078613258292743
9,970449285785183; 7,570248682233174
11,45199010216502; 9,555025798104364
12,996524264845444; 11,650051282765677
14,44750438384932; 13,105875838242486
15,932876170840391; 13,151262391883911
17,955541586056665; 13,197122592800905
23,960588019161822; 13,202416297645517
```

Copy to Clipboard | Download .CSV | Graph in Plotly* | Close

*Plotly is a secure data analysis and graphing site with data sharing and access controls.

Visit http://plot.ly for details.

Sort
Sort by: Raw
Order: Ascending

Format
Number Formatting:
Digits: 5 Ignore
Column Separator: ;
Format

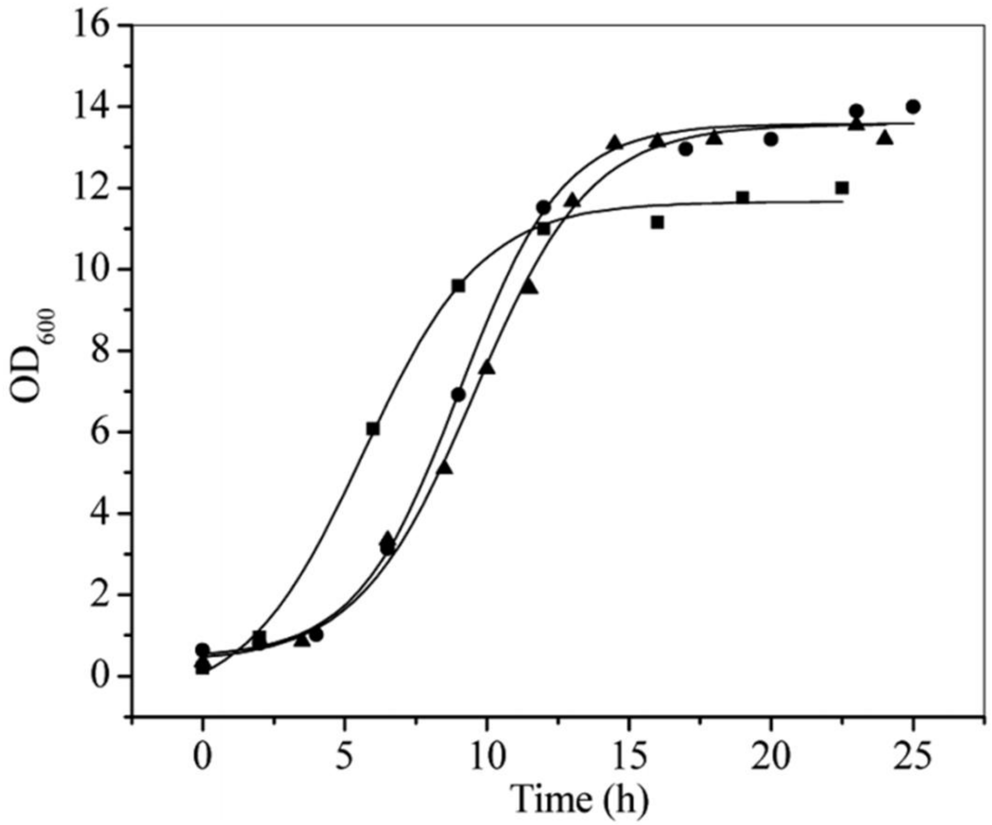


Figure 2. Growth curves for three yeasts obtained by optical density at 600 nm: *S. cerevisiae* (■), *P. tannophilus* (●), and *P. stipitis* (▲). The incubation conditions are stated in the text.

●	
0	0,658929
3,978346	0,985998
6,502573	3,121514
8,96028	6,932019
11,98532	11,53541
17,00787	12,91942
19,94663	13,20333
22,94786	13,86184
24,97044	13,94821

▲	
0	0,310768
3,504598	0,842786
6,470509	3,379836
8,521515	5,078613
9,970449	7,570249
11,45199	9,555026
12,99652	11,65005
14,4475	13,10588
15,93288	13,15126
17,95554	13,19712
23,96059	13,20242

■	
0	0,14447
2,002861	0,88814
5,972818	6,039103
9,048641	9,571912
12,01717	10,96163
15,98712	11,10325
19,06295	11,72017
22,53219	11,93755

Fitting the Richards Model to Response Data

AIC_c= 12,5163823   BIC= -17,08641

Stopping Critical point: 100% 100%

Clear Data Range

HOME   Save

Data

Point	Input (x)	Output (y)	Residuals	Expected	Qm
1	0	0,144469848	0,0359	0,11	0,01
2	2,00286	0,888140156	-0,0026	0,89	0,00
3	5,97282	6,039103481	-0,0360	6,08	0,00
4	9,04864	9,57191181	0,0854	9,49	0,00
5	12,0172	10,96163188	0,0355	10,93	0,00
6	15,9871	11,10324941	-0,4198	11,52	0,02
7	19,0629	11,72016989	0,0765	11,64	0,00
8	22,5322	11,93755209	0,2539	11,68	0,01

Sample Statistics

Min Input	0,0000	Min Output	0,14
Max Input	22,5322	Max Output	11,94

Regression

a	b	c	d	SSE
11,6982	1,14531	0,38126	4,9898	0,2577
11,4564	0,6901	0,3813	4,9898	Lower 95% Confidence Levels
11,9400	1,6006	0,3813	4,9898	Upper 95% Confidence Levels
0,1234	0,2323	0,0000	0,0000	Standard Errors
94,81862633	4,930969431	2032904846	2032904787	t-Statistics
P<0.0001	0,0079	P<0.0001	P<0.0001	p-values

Goodness of Fit (R^2_{adj}) 99,845%   Qm = 0,0342786555516808   Critical Xi^2 = 7,814727903

Regression models with Qm> critical Xi^2, indicating inadequate fits, are highlighted in red

Instructions

Instructions	Min Input	Max Input
1. Copy data in cells "Input and Output"	0	22,53219
	Output	Output
2. View the data and estimate the value for "a and d"	0,109	11,684

3. Guess values of "b and c" until the predicted line is close to the observed points

4. Press the button below to run solver with current settings

Fit Richards Model to Current Data   Learning Model

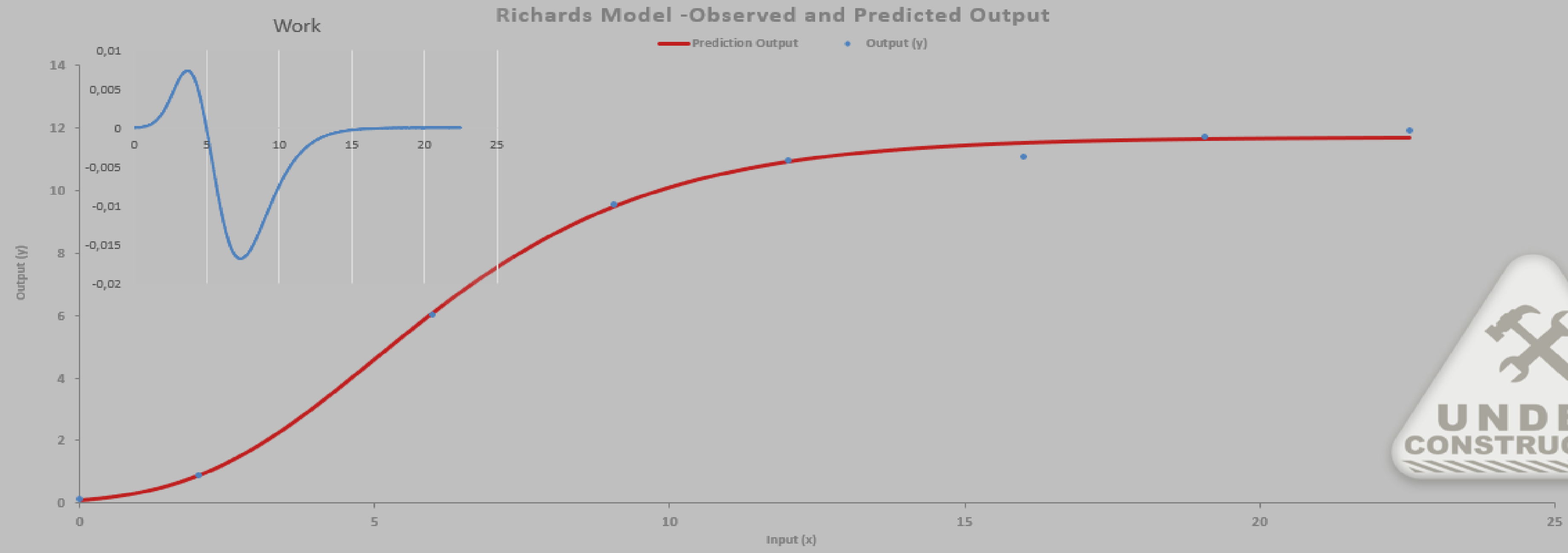
5. Solver will attempt to minimize SSE by changing values of "a, b, c and d"

The optimization process may take a few minutes, depending on your computer's speed.

Inputs

Functional Form

$$y = a\,[\,1+(b-1)e^{-c(x-d)}\,]^{1/(1-b)}$$



Maximum growth rate (velocity)=	1,5308
Average growth rate (velocity)=	1,0395
Weight at inflection point*=	4,5985
* where the autoacceleration growth phase passes into the autoretartion phase	
Pi weight/a=	39,3098%

a= the upper asymptote (mature);

b= a shape parameter, with the property that b^(1/(1-b)) is relative weight at **d**;

c= the maximum relative growth;

d= the age at maximum rate of growth".

UNDER CONSTRUCTION

Fitting the Richards Model to Response Data AIC$_c$= 8,656636647 BIC= -10,3572405

Stopping Critical point

Clear Data Range

100% 100%

HOME

Save

Data

Point	Input (x)	Output (y)	Residuals	Expected	Qm
1	0	0,65892924	0,4635	0,20	1,10
2	3,97835	0,985997754	-0,1378	1,12	0,02
3	6,50257	3,121513587	-0,0218	3,14	0,00
4	8,96028	6,93201919	-0,0070	6,94	0,00
5	11,9853	11,53541309	0,1091	11,43	0,00
6	17,0079	12,91941525	-0,4821	13,40	0,02
7	19,9466	13,20332599	-0,3185	13,52	0,01
8	22,9479	13,86183731	0,3167	13,55	0,01
9	24,9704	13,94820858	0,3995	13,55	0,01

Sample Statistics

Min Input	0,0000	Min Output	0,66
Max Input	24,9704	Max Output	13,95

Regression

a	b	c	d	SSE
13,5504	2,26309	0,56532	9,0499	0,8401
13,1804	1,8576	0,5652	9,0474	Lower 35% Confidence Levels
13,9203	2,6686	0,5655	9,0525	Upper 35% Confidence Levels
0,1888	0,2069	0,0001	0,0013	Standard Errors
71,78746626	10,93941975	6957,584824	6947,606998	t-Statistics
P<0.0001	0,0001	P<0.0001	P<0.0001	p-values

Goodness of Fit (R^2_{adj}) 99,675% Qm = 1,16174592620275 Critical Xi^2 = 9,487729037

Regression models with Qm> critical Xi^2, indicating inadequate fits, are highlighted in red

Instructions

1. Copy data in cells "**Input** and **Output**"
2. View the data and estimate the value for "**a** and **d**"
3. Guess values of "**b** and **c** " until the predicted line is close to the observed points
4. Press the button below to run solver with current settings

Fit Richards Model to Current Data | Learning Model

5. Solver will attempt to minimize SSE by changing values of "**a, b, c** and **d**"

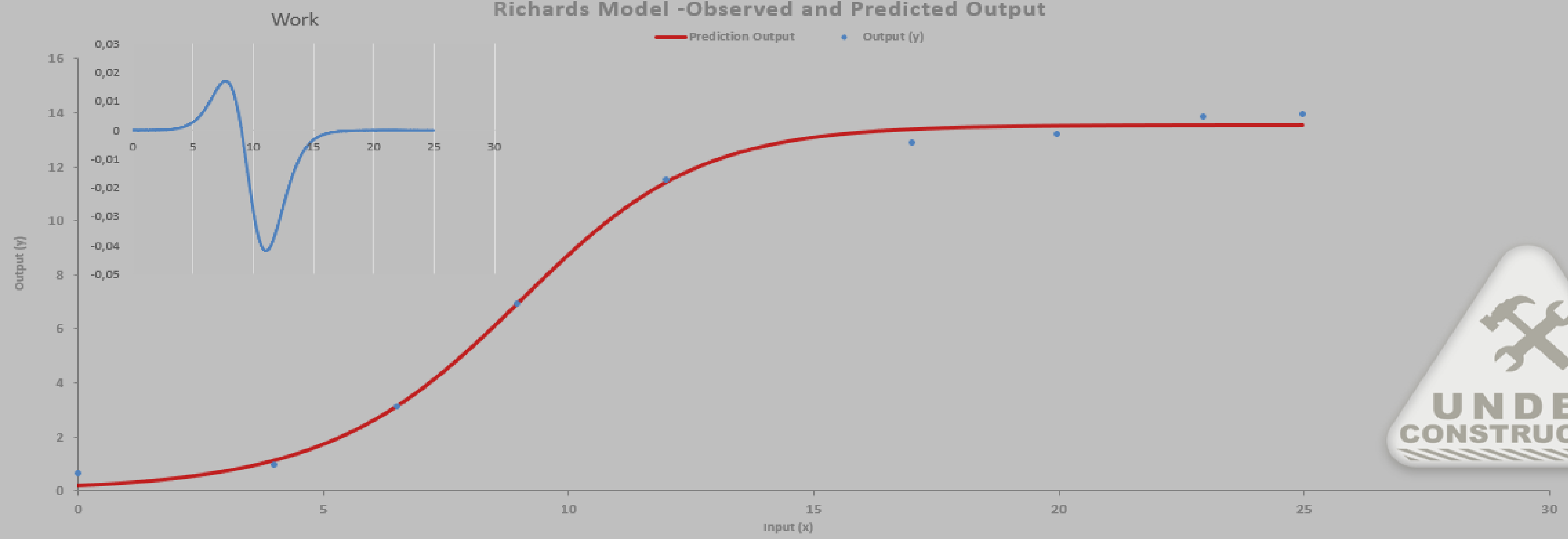
The optimization process may take a few minutes, depending on your computer's speed.

Min Input	Max Input
0	24,97044
Output	**Output**
0,195	13,549

Inputs

Functional Form

$$y = a\left[1+(b-1)e^{-c(x-d)}\right]^{1/(1-b)}$$



a= the upper asymptote (mature);

b= a shape parameter, with the property that b^(1/(1-b)) is relative weight at **d**;

c= the maximum relative growth;

d= the age at maximum rate of growth*.

Maximum growth rate (velocity)=	1,7731
Average growth rate (velocity)=	1,1738
Weight at inflection point*=	7,0979
Pi weight/a=	52,3817%

* where the autoacceleration growth phase passes into the autoretartion phase

UNDER CONSTRUCTION

Fitting the Richards Model to Response Data

AIC$_c$= -8,39368454 BIC= -18,4042082

Stopping Critical point: 100% 100%

Clear Data Range

Data

Point	Input (x)	Output (y)	Residuals	Expected	Qm
1	0	0,310768336	-0,1406	0,45	0,04
2	3,5046	0,842785673	-0,4091	1,25	0,13
3	6,47051	3,379835512	0,4347	2,95	0,06
4	8,52152	5,078613258	-0,1091	5,19	0,00
5	9,97045	7,570248682	0,1654	7,40	0,00
6	11,452	9,555025798	-0,2704	9,83	0,01
7	12,9965	11,65005128	-0,0933	11,74	0,00
8	14,4475	13,10587584	0,4057	12,70	0,01
9	15,9329	13,15126239	0,0372	13,11	0,00
10	17,9555	13,19712259	-0,0967	13,29	0,00
11	23,9606	13,2024163	-0,1471	13,35	0,00
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Sample Statistics

Min Input	0,0000	Min Output	0,31
Max Input	23,9606	Max Output	13,20

HOME

Save

Regression

a	b	c	d	SSE
13,3502	3,46906	0,71941	10,3676	0,6941
13,0753	3,1214	0,7194	10,3670	Lower 95% Confidence Levels
13,6252	3,8167	0,7195	10,3682	Upper 95% Confidence Levels
0,1403	0,1774	0,0000	0,0003	Standard Errors
95,16672715	19,5576105	32742,0229	32678,15157	t-Statistics
P<0.0001	P<0.0001	P<0.0001	P<0.0001	p-values

Goodness of Fit (R^2_{adj}) 99,735% Qm = 0,271186206590683 Critical Xi^2 = 12,59158724

Regression models with Qm> critical Xi^2, indicating inadequate fits, are highlighted in red

Instructions

Min Input	Max Input
0	23,96059
Output	Output
0,451	13,349

1. Copy data in cells "**Input** and **Output**"
2. View the data and estimate the value for "**a** and **d**"
3. Guess values of "**b** and **c** " until the predicted line is close to the observed points
4. Press the button below to run solver with current settings

Fit Richards Model to Current Data

Learning Model

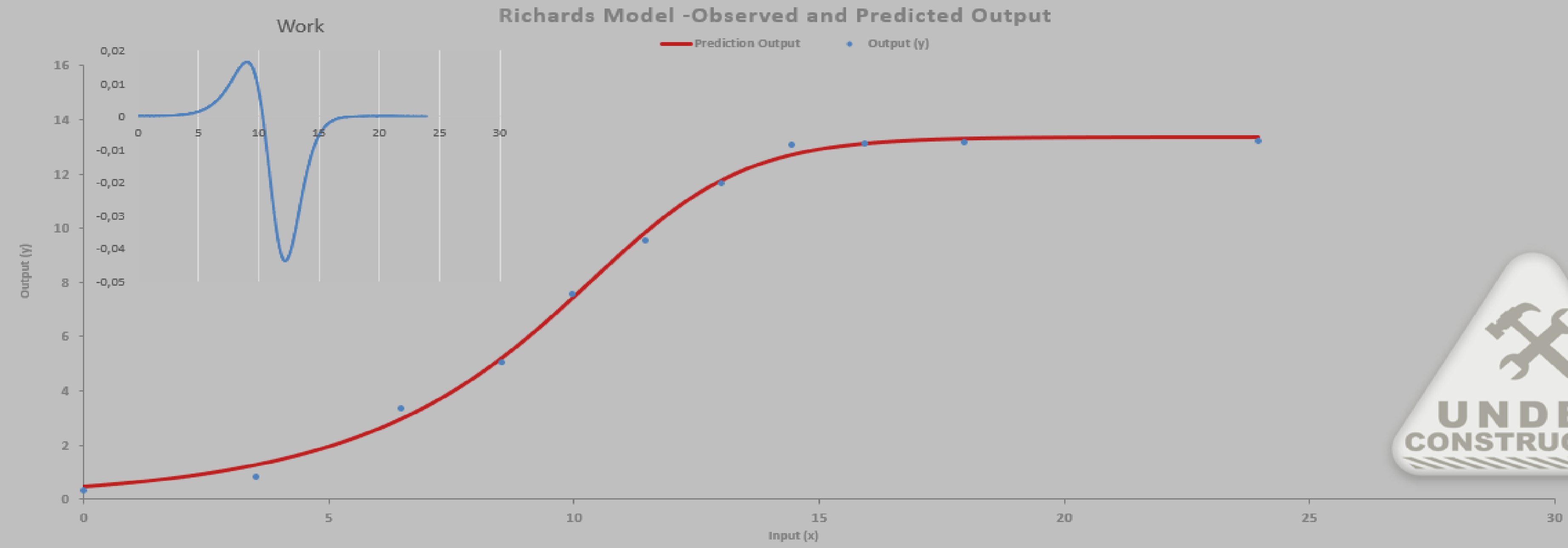
5. Solver will attempt to minimize SSE by changing values of "**a, b, c** and **d**"

The optimization process may take a few minutes, depending on your computer's speed.

Inputs

Functional Form

$$y = a\left[1+(b-1)e^{-c(x-d)}\right]^{1/(1-b)}$$



Maximum growth rate (velocity)= 1,6729

Average growth rate (velocity)= 1,0745

Weight at inflection point*= 8,0667

* where the autoacceleration growth phase passes into the autoretardation phase

Pi weight/a= 60,4237%

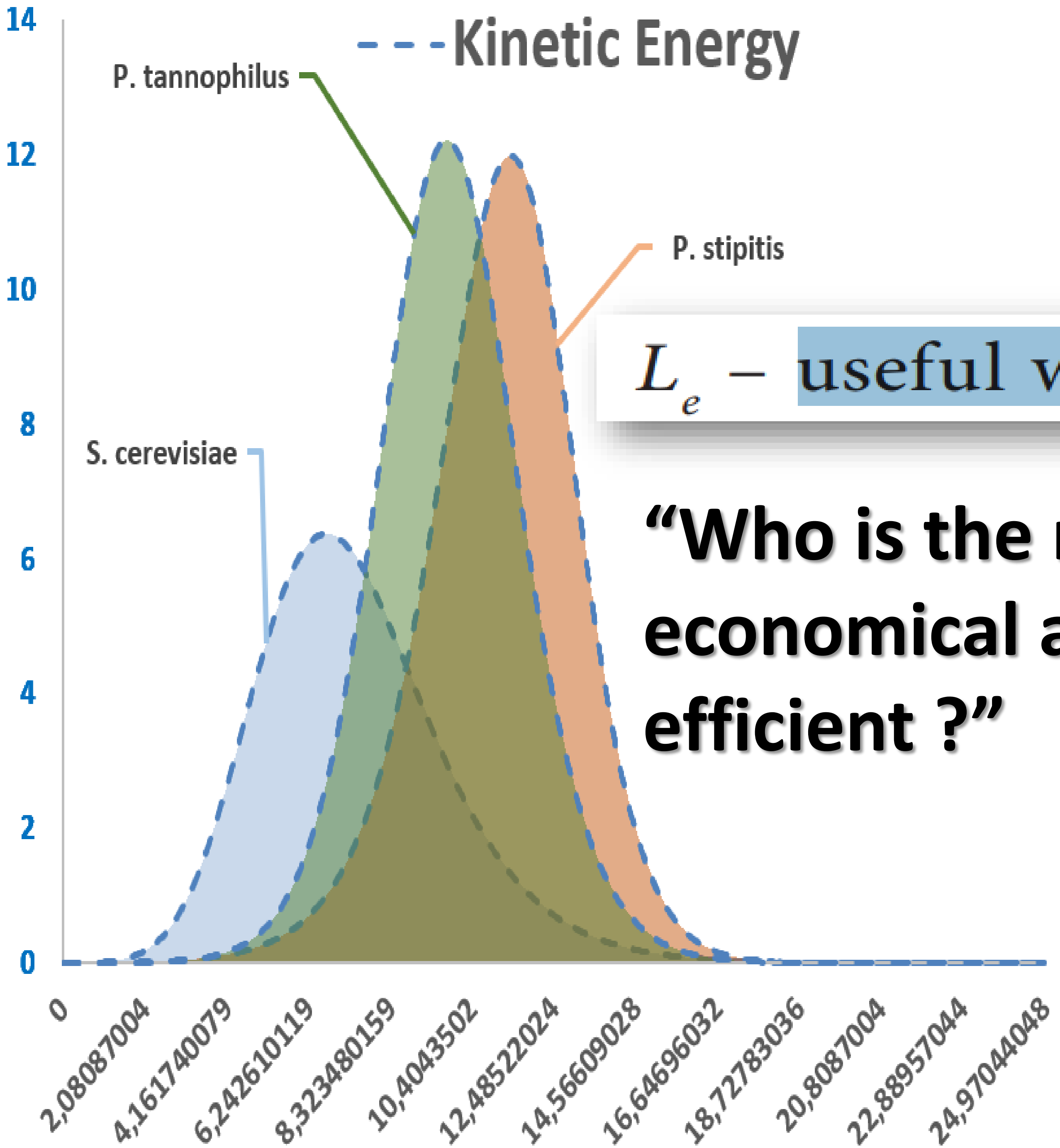
a= the upper asymptote (mature);

b= a shape parameter, with the property that b^(1/(1−b)) is relative weight at **d**;

c= the maximum relative growth;

d= the age at maximum rate of growth".

UNDER CONSTRUCTION



	KEm_Total (sum) "Action"	Index
P. tan	6606,37	100,00%
P. sti	6530,82	98,86%
S. cer	4306,01	65,18%

L_e – useful work

"Who is the most economical and efficient ?"

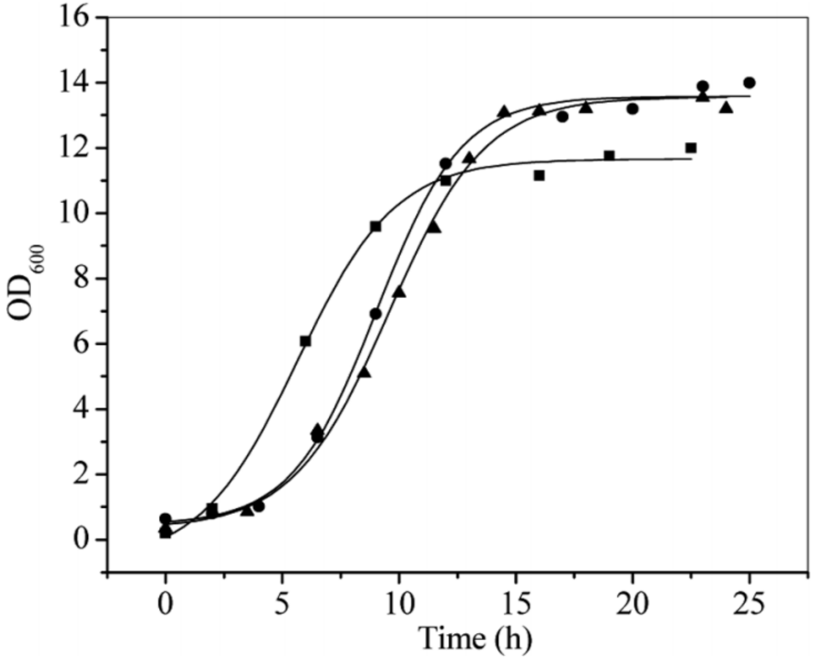


Figure 2. Growth curves for three yeasts obtained by optical density at 600 nm: *S. cerevisiae* (■), *P. tannophilus* (●), and *P. stipitis* (▲). The incubation conditions are stated in the text.

JOURNAL OF ANIMAL SCIENCE
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A multilevel nonlinear mixed-effects approach to model growth in pigs

A. B. Strathe, A. Danfær, H. Sørensen and E. Kebreab

J Anim Sci 2010.88:638-649.
doi: 10.2527/jas.2009-1822 originally published online Oct 23, 2009;

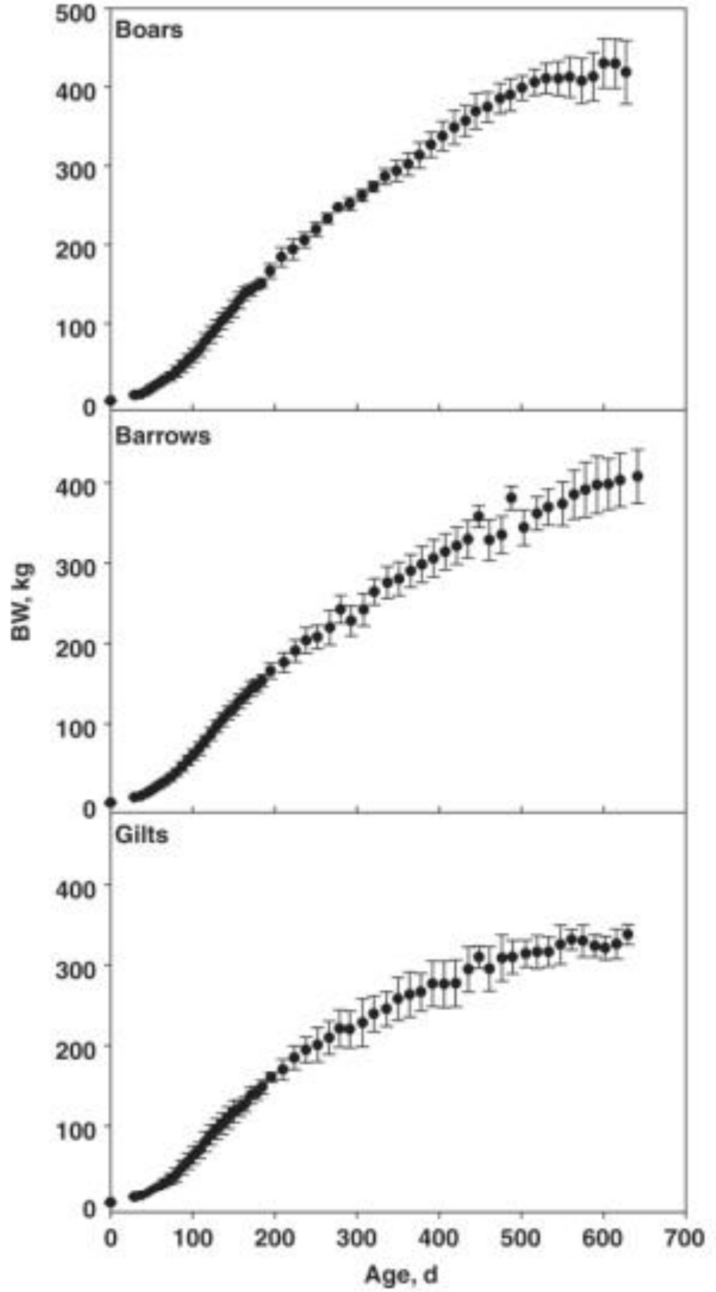
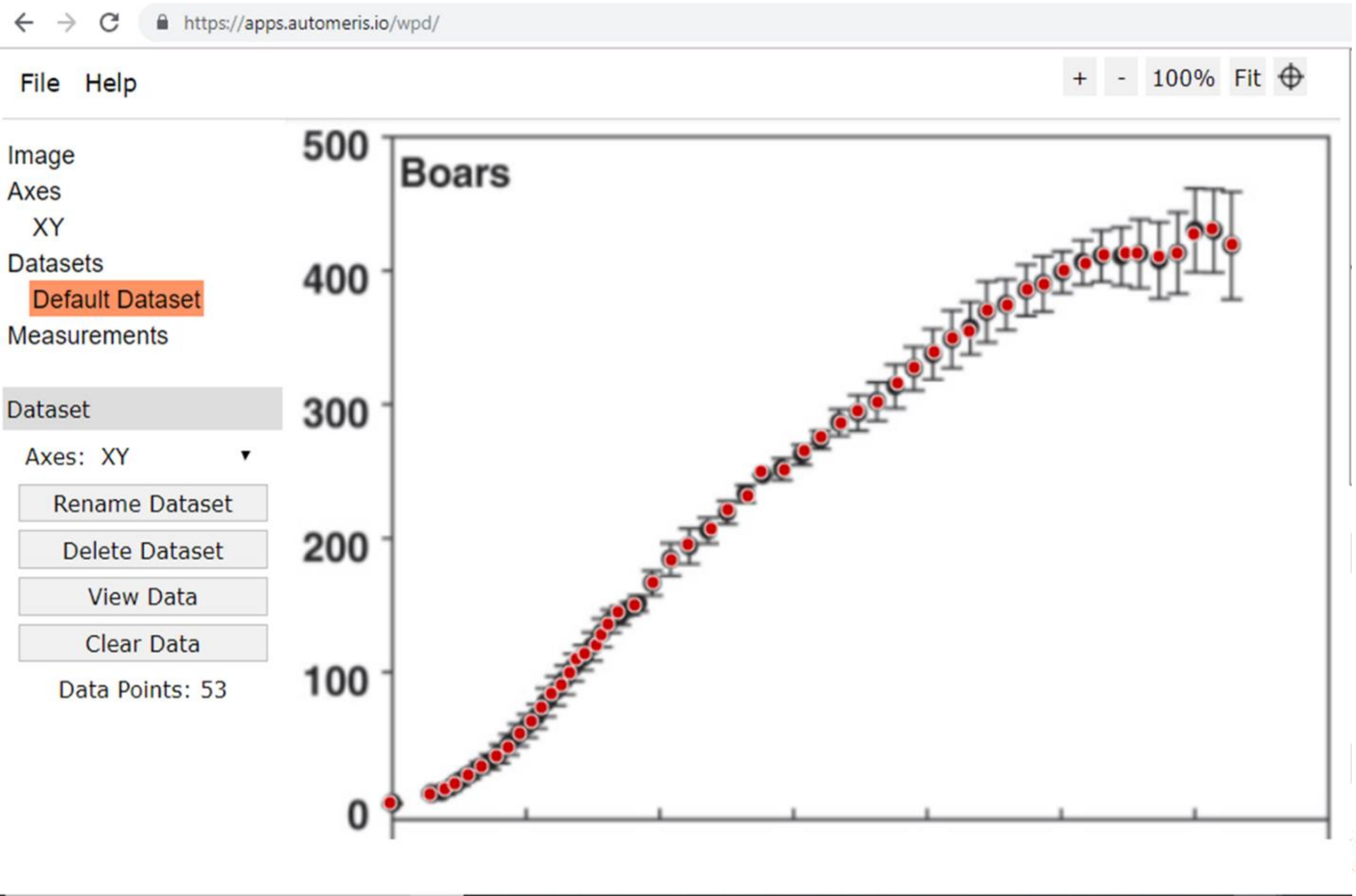


Figure 1. Average BW (kg) as a function of age (d) and grouped by sex (i.e., barrow, boar, and gilt). Error bars (SD) are included to show how the variance increases as a function of age.



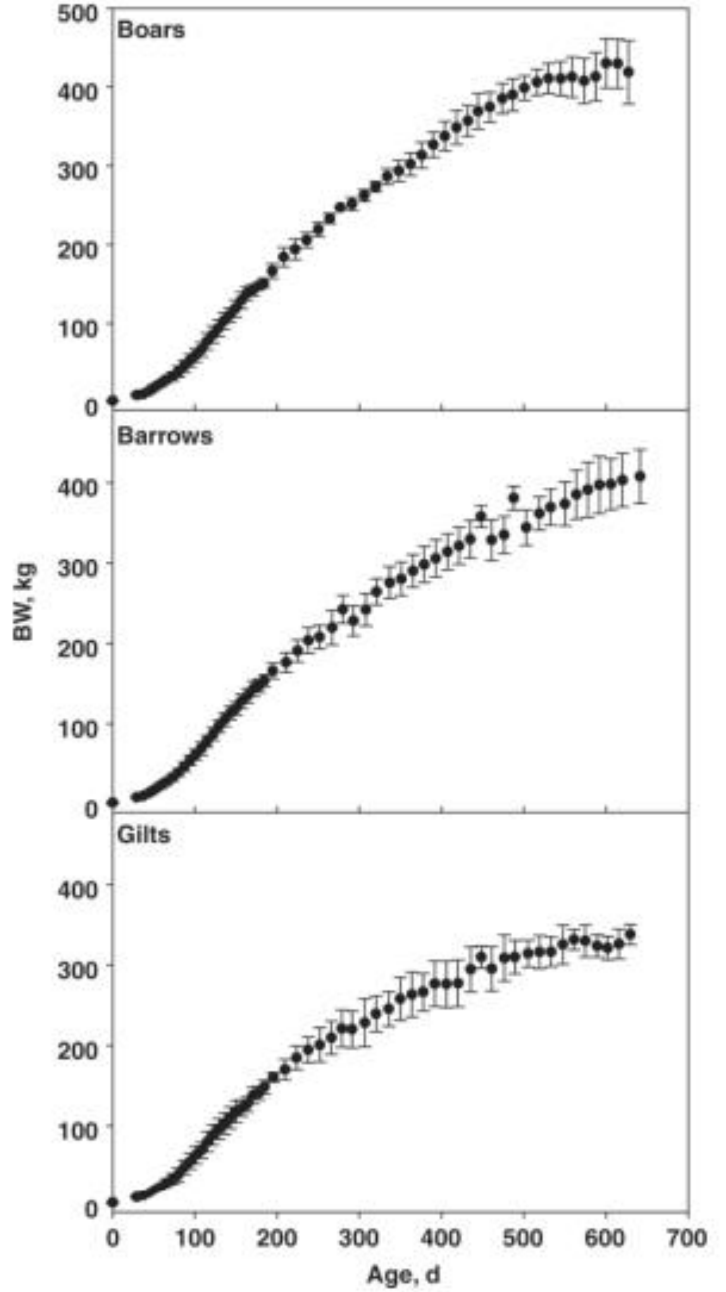


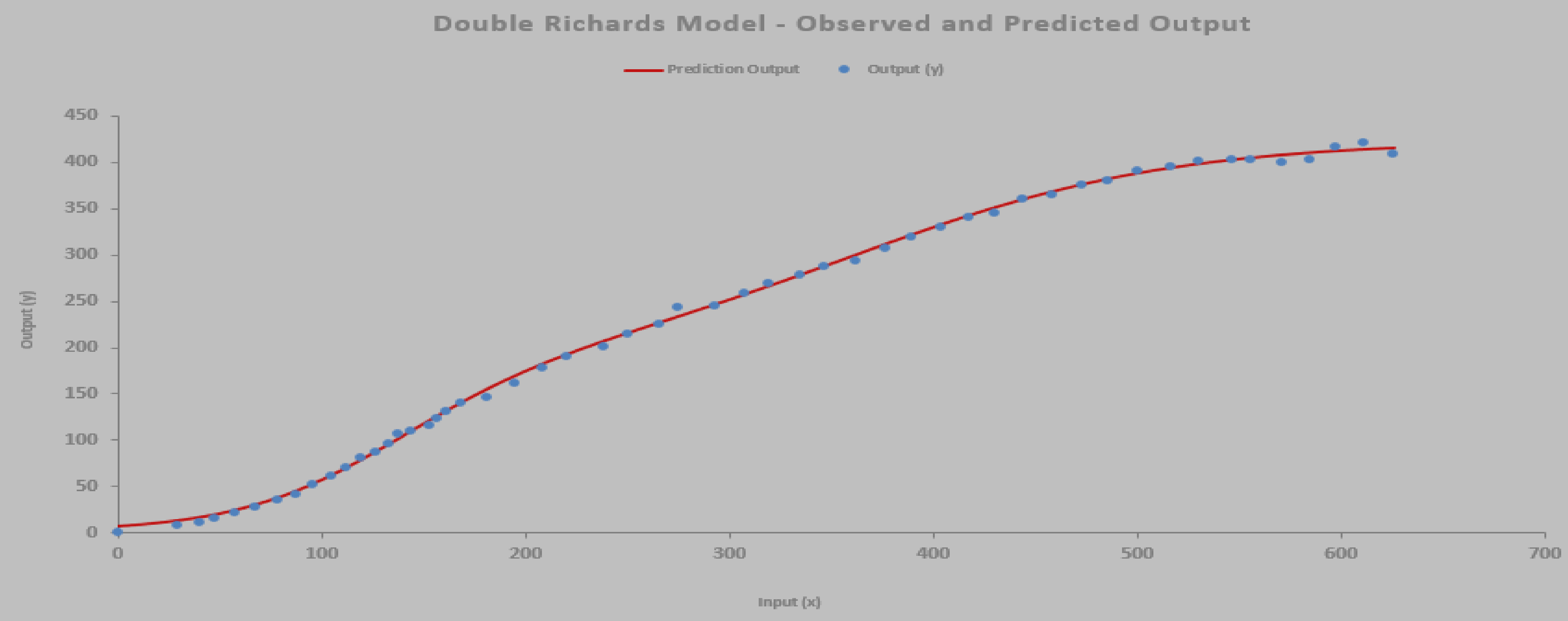
Figure 1. Average BW (kg) as a function of age (d) and grouped by sex (i.e., barrow, boar, and gilt). Error bars (SD) are included to show how the variance increases as a function of age.

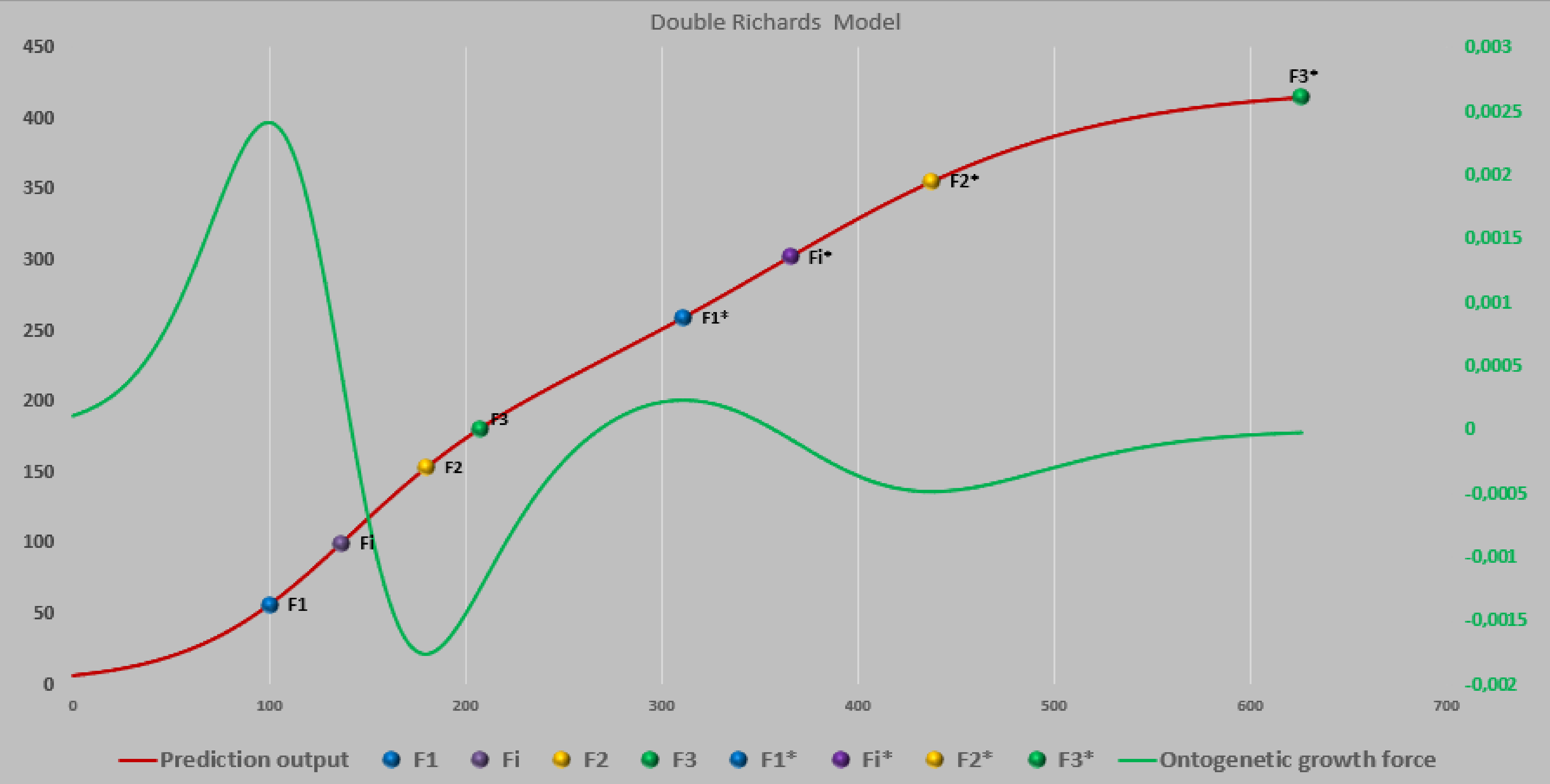
Regression								
a	**b**	**c**	**d**	**a'**	**b'**	**c'**	**d'**	*SSE*
180,6588801	1,83196463	0,023746832	136,987185	422,3207451	2,070082276	0,013184148	365,5398474	729,8034
Goodness of Fit (R^2): 99,929%		Qm = 10,2285175015156					Critical Xi^2 =	*62,82962041*

Regression models with Qm> critical Xi^2, indicating inadequate fits, are highlighted in red

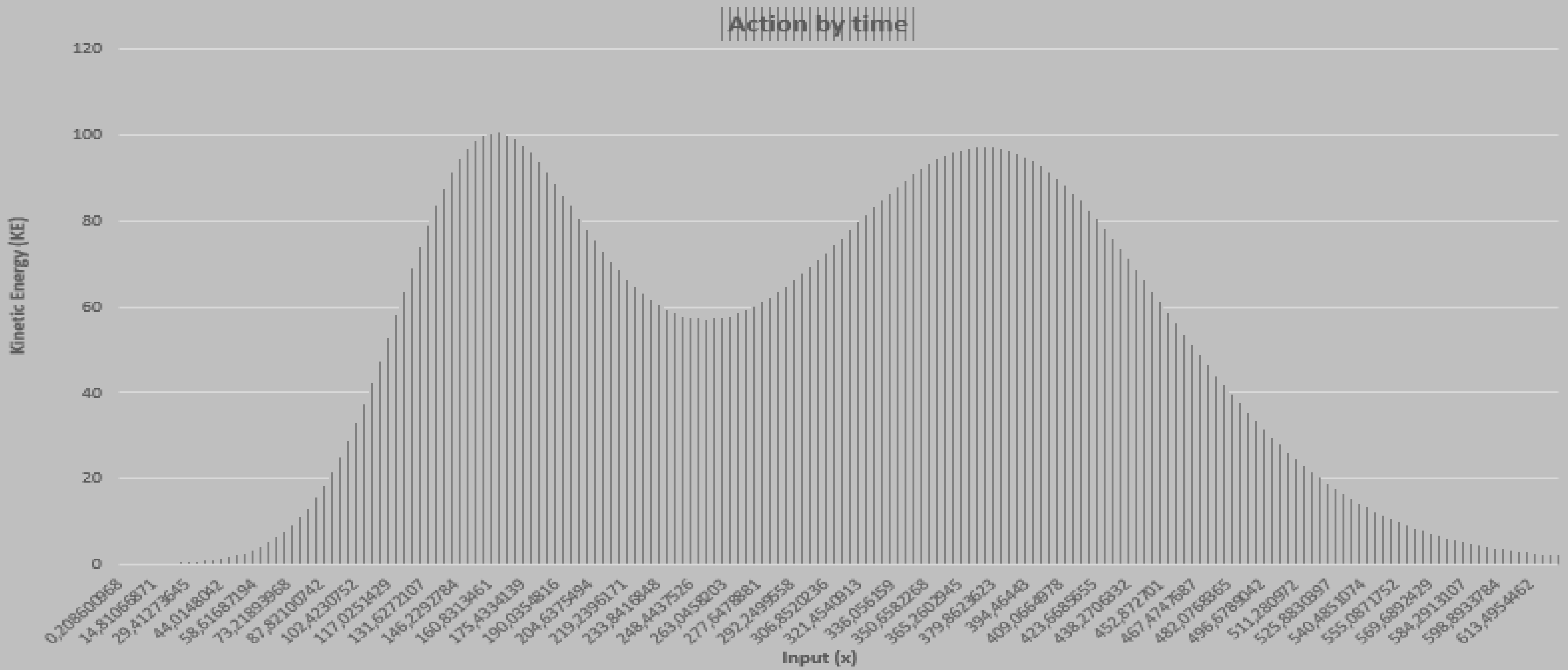
Functional Form

$$y = a\left[1+(b-1)e^{-c(x-d)}\right]^{1/(1-b)} + (a'-a)\left[1+(b'-1)e^{-c'(x-d')}\right]^{1/(1-b')}$$





Double Richards Model based on first principles of energy



Kinetic Energy (KE)			Time	Weight
$KE_{maximum}$ =	100,39	1,0039E+02	163,335	133,773

By Time

ACTION =	149.986,28	1,4999E+05	**626,012**	414,776

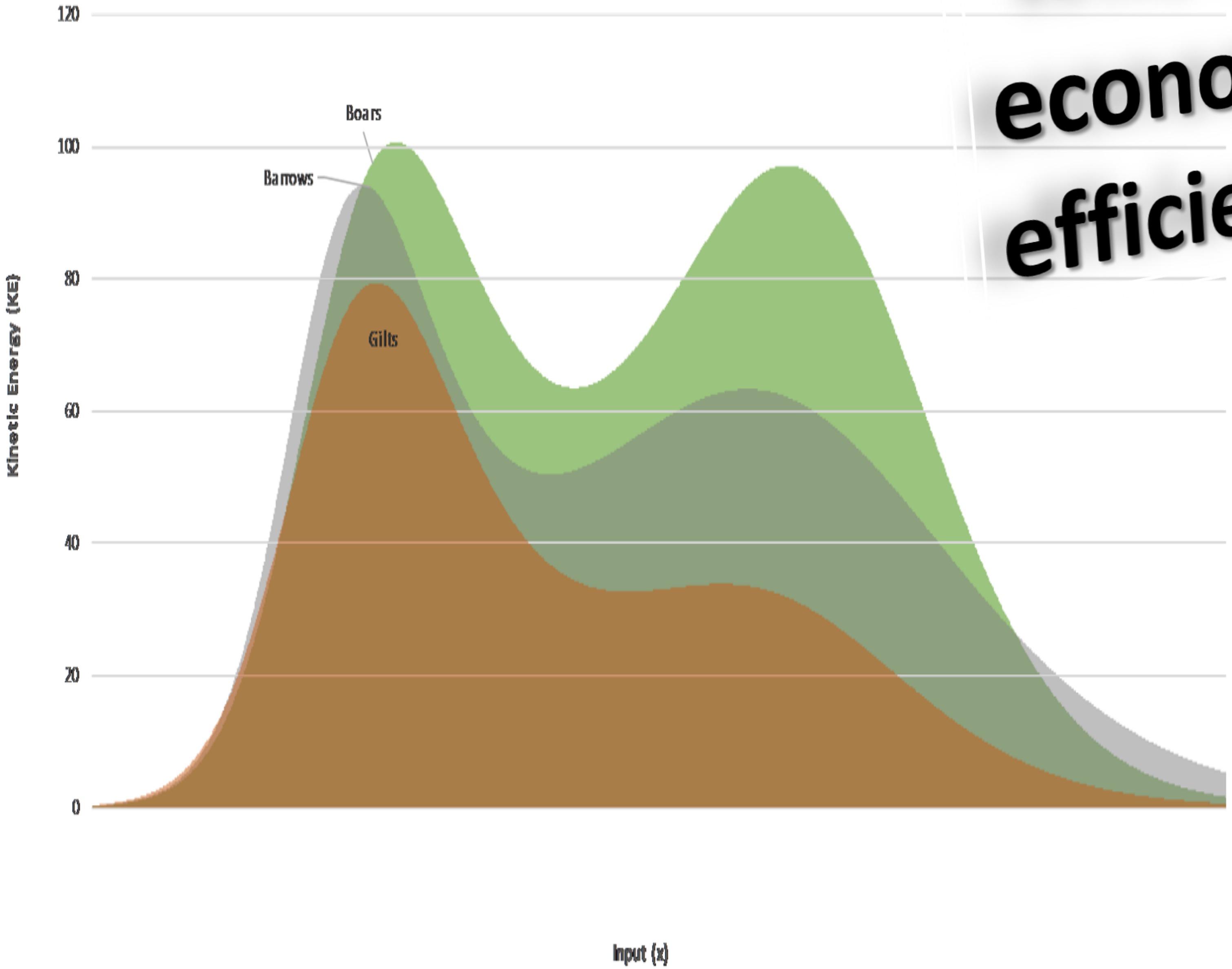
Theory of growth based on first principles of energy co

$$KE=m*v^2/2$$

KE= Kinetic Energ
m=total biomass
v=velocity

Power tells you how fast a job is done (J / s). The action, on the other l
work is in a given period of time (J × s) (Girtler, 2011).
The action presents as quantitative base the dimension energy × time.

"Who is the most economical and efficient ?"



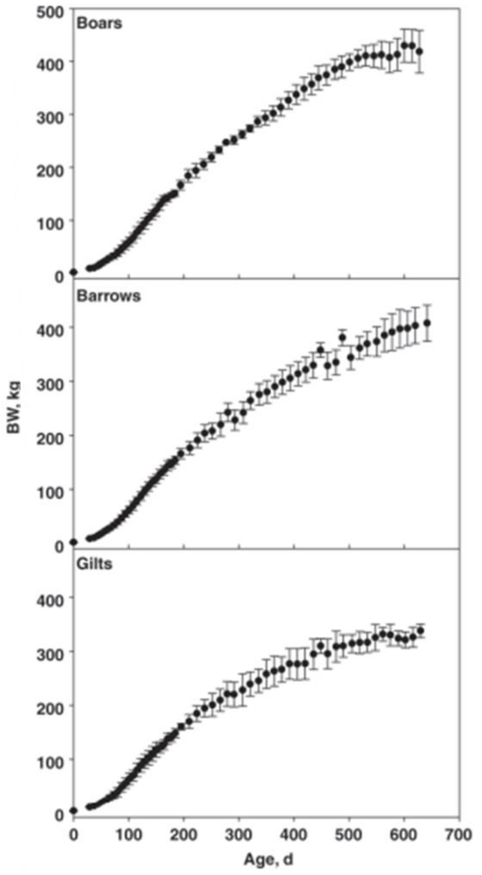
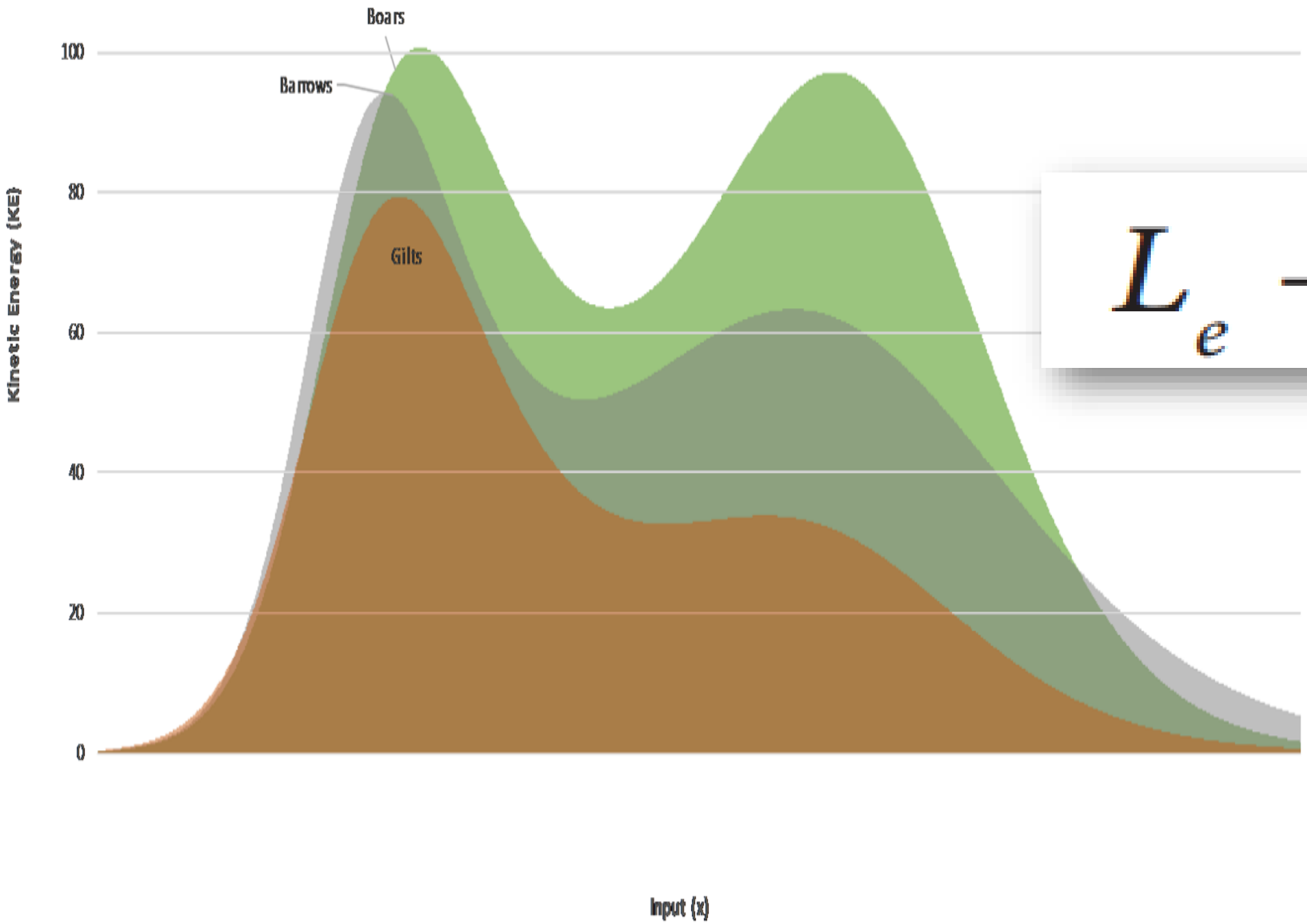


Figure 1. Average BW (kg) as a function of age (d) and grouped by sex (i.e., barrow, boar, and gilt). Error bars (SD) are included to show how the variance increases as a function of age.

		Index 100	
Gilts	83314,32	52,99433	47,00567
Barrows	128504,8	81,73895	18,26105
Boars	157213,7	100	

system maintenance. The trend to most action (energy x time) expresses the innate capacity of organisms to acquire, concentrate, and conserve energy. Thus, in an ecosystem, the capacity of the



L_e – useful work

		Index 100	
Gilts	83314,32	52,99433	47,00567
Barrows	128504,8	81,73895	18,26105
Boars	157213,7	100	

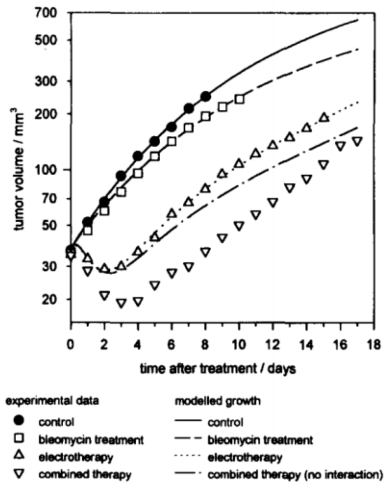
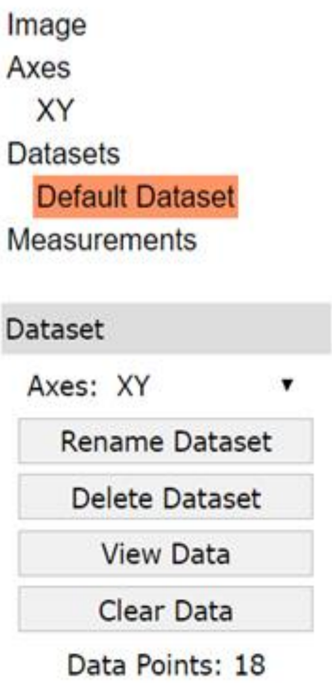
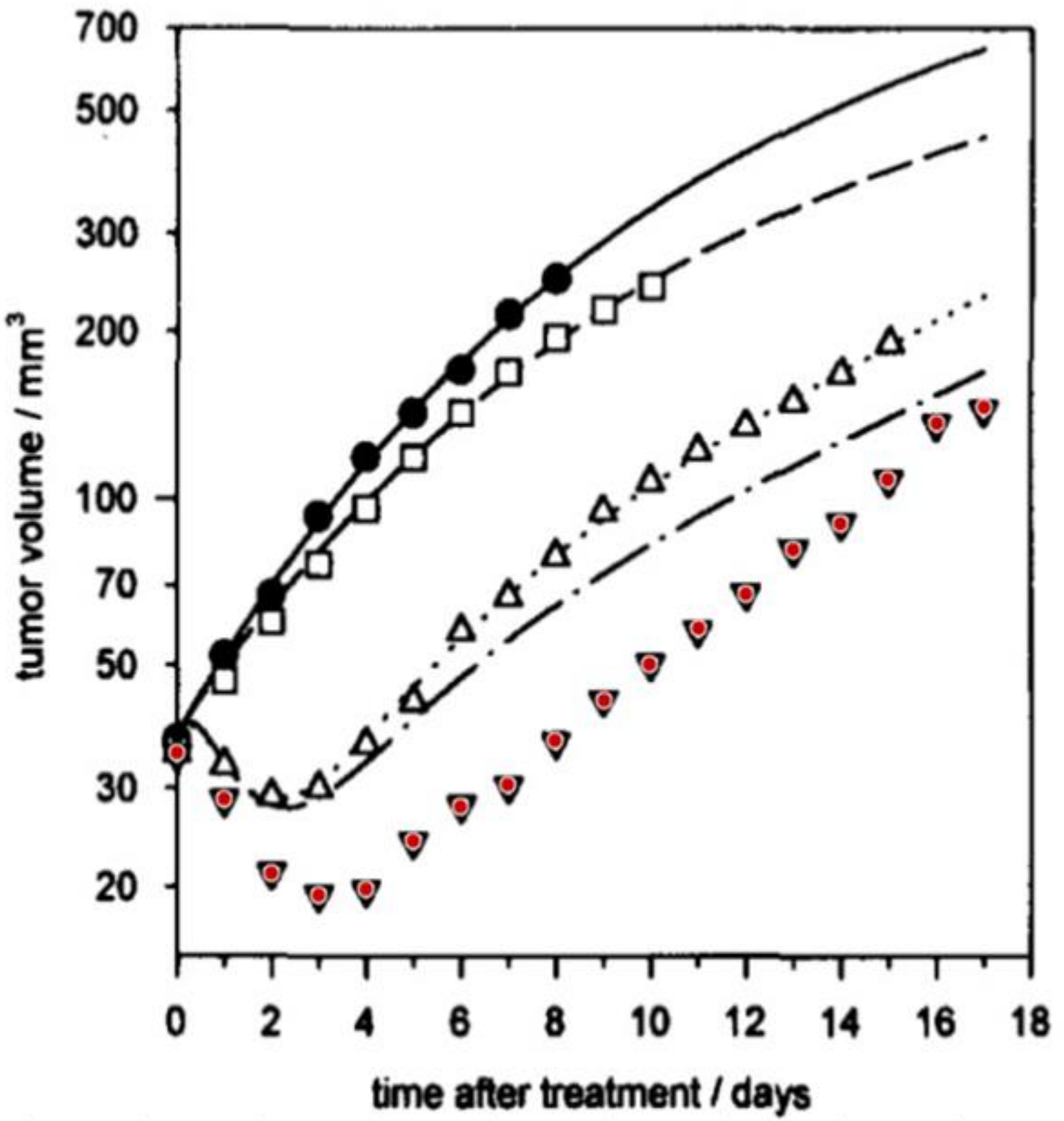


Fig. 1. Experimental data and modelled growth curves.

0	153,3615
0,988833	118,5216
1,987599	62,42363
2,98412	45,80488
3,979431	50,44416
4,972928	86,97048
5,96703	112,8678
6,961651	129,6545
7,955321	163,144
8,988986	193,5999
9,943179	221,0123
10,97702	248,4314
11,97112	274,3287
12,96479	307,8182
13,95924	327,6418
14,95291	361,1312
15,98588	403,7346
16,98076	415,9661

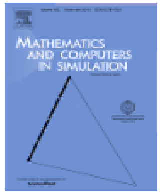




ELSEVIER

Mathematics and Computers in Simulation

Volume 39, Issues 5–6, 30 November 1995, Pages 597-602



Mathematical modelling of tumor growth in mice following electrotherapy and bleomycin treatment

Damijan Miklavčič [a], Tomaž Jarm [a], Rihard Karba [a], Gregor Serša [b]

Clear Data Range

HOME

Point	Input (x)	Output (y)	Residuals	Expected	Qm
1	0	152,5568	0,2897	152,267	6E-04
2	0,9411765	145,9506	-0,6201	146,571	0,003
3	1,9411765	121,3958	1,8148	119,581	0,028
4	2,9411765	126,0076	-8,0071	134,015	0,478
5	3,9411765	159,7861	-3,4010	163,187	0,071
6	4,9411765	191,321	-5,0020	196,323	0,127
7	5,9411765	245,2918	13,9278	231,364	0,838
8	6,9411765	272,3395	5,4867	266,853	0,113
9	7,9411765	303,8744	2,5259	301,349	0,021
10	9	335,4167	0,0285	335,388	2E-06
11	9,8823529	357,9625	-3,0571	361,02	0,026
12	11	385,0249	-4,2998	389,325	0,047
13	11,941176	403,091	-6,3318	409,423	0,098
14	13	421,1717	-6,9520	428,124	0,113
15	14	441,4886	-0,8632	442,352	0,002
16	15	466,2927	12,5914	453,701	0,349
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Sample Statistics

Min Input	0,0000	Min Output	121,40
Max Input	15,0000	Max Output	466,29

Save

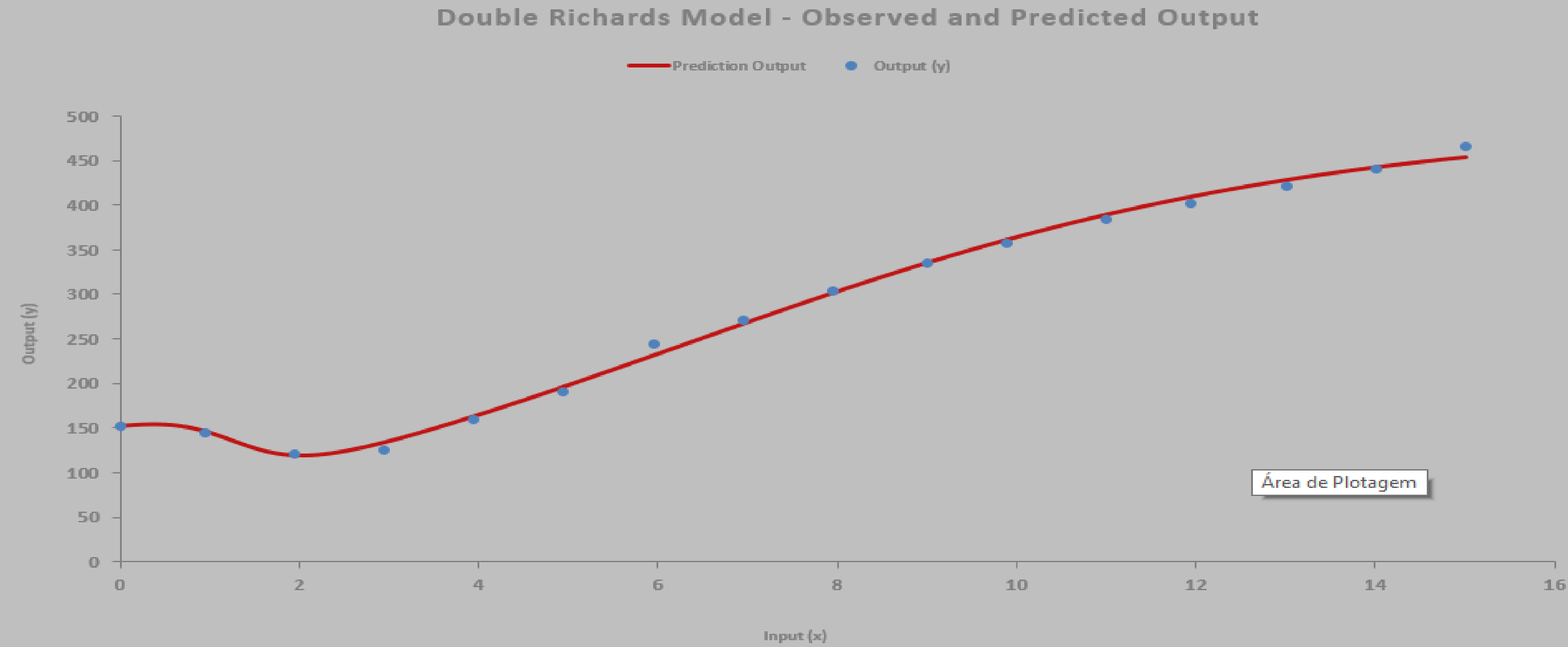
Regression

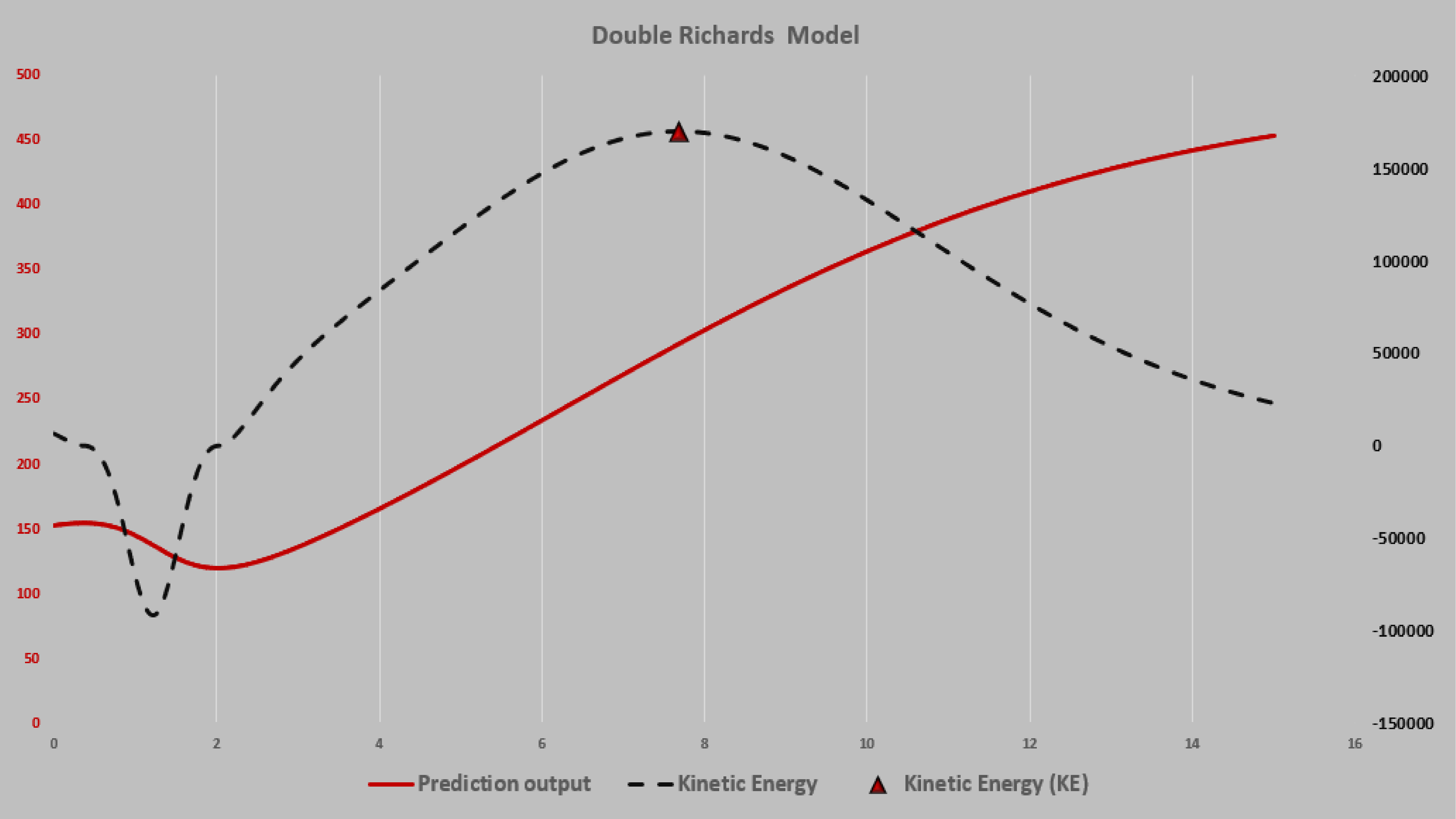
a	b	c	d	a'	b'	c'	d'	SSE
89,38010631	2,04550357	-2,655319763	1,26553875	581,7429199	1,91683993	0,281649385	6,244286012	610,4748
-2059,669079	-24,08972679	-6,515557252	-7,396179448	-3169,130384	-4,28440196	-0,08567307	-23,57766529	wer 95% Confidence Levels
2238,429291	28,18073393	1,204917726	9,927256957	4332,616224	8,11808182	0,648971839	36,06623732	per 95% Confidence Levels
1096,453666	13,3343012	1,969508923	4,419243981	1913,710869	3,163898923	0,187409416	15,21528128	Standard Errors
0,081517449	0,153401633	-1,348214132	0,286369967	0,30398684	0,605847398	1,502856107	0,4103957	t-Statistics
0,937033008	0,881880422	0,21451578	0,781870873	0,768894409	0,561407345	0,171280508	0,692286935	p-values
Goodness of Fit (R^2_{adj}) 99,726%		Qm = 2,31518194532028					Critical Xi^2 =	14,06714045

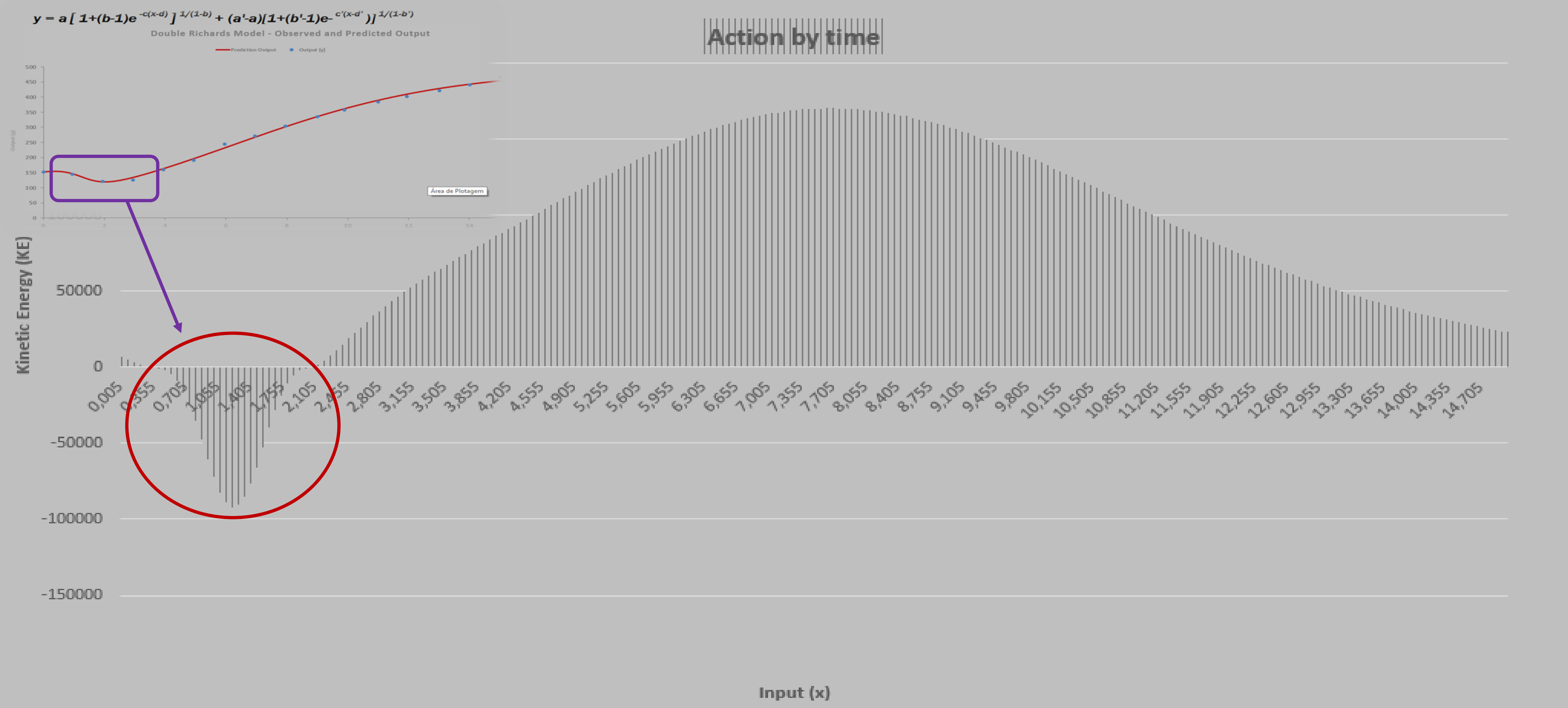
Regression models with Qm>critical Xi^2, indicating inadequate fits, are highlighted in red

Functional Form

$$y = a\left[1+(b-1)e^{-c(x-d)}\right]^{1/(1-b)} + (a'-a)\left[1+(b'-1)e^{-c'(x-d')}\right]^{1/(1-b')}$$




Double Richards Model
500
450
400
350
300
250
200
150
100
50
0
200000
150000
100000
50000
0
-50000
-100000
-150000
0
2
4
6
8
10
12
14
16
Prediction output
Kinetic Energy
Kinetic Energy (KE)



Kinetic Energy (KE)			Input	Output
$KE_{maximum}$ =	170.179,83	1,7018E+05	7,685	292,681

By input

ACTION =	###########	2,4796E+08	**15,005**	453,752

Theory of growth based on first principles of energy conserva

$$KE=m*v^2/2$$

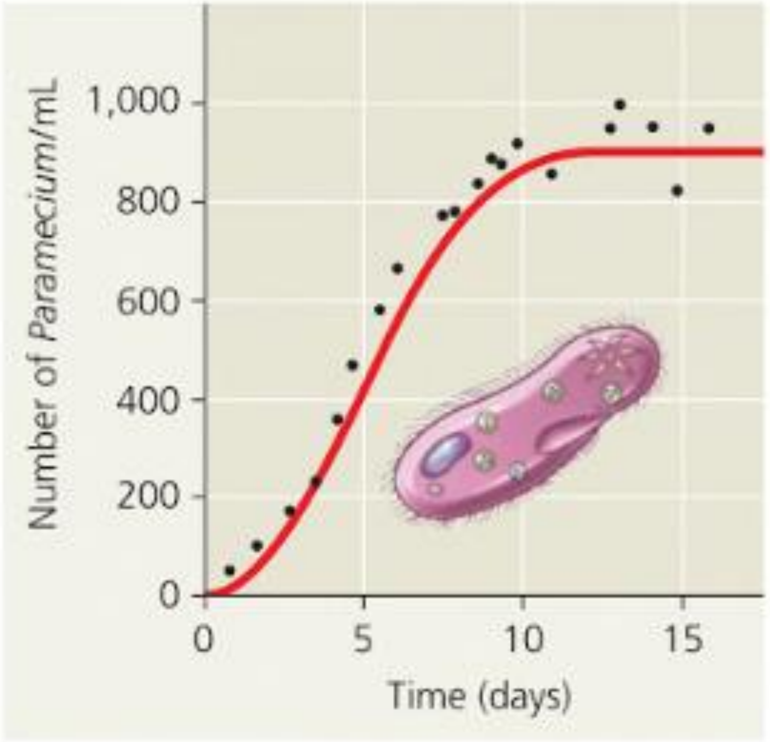
KE= Kinetic Energy

m=total biomass

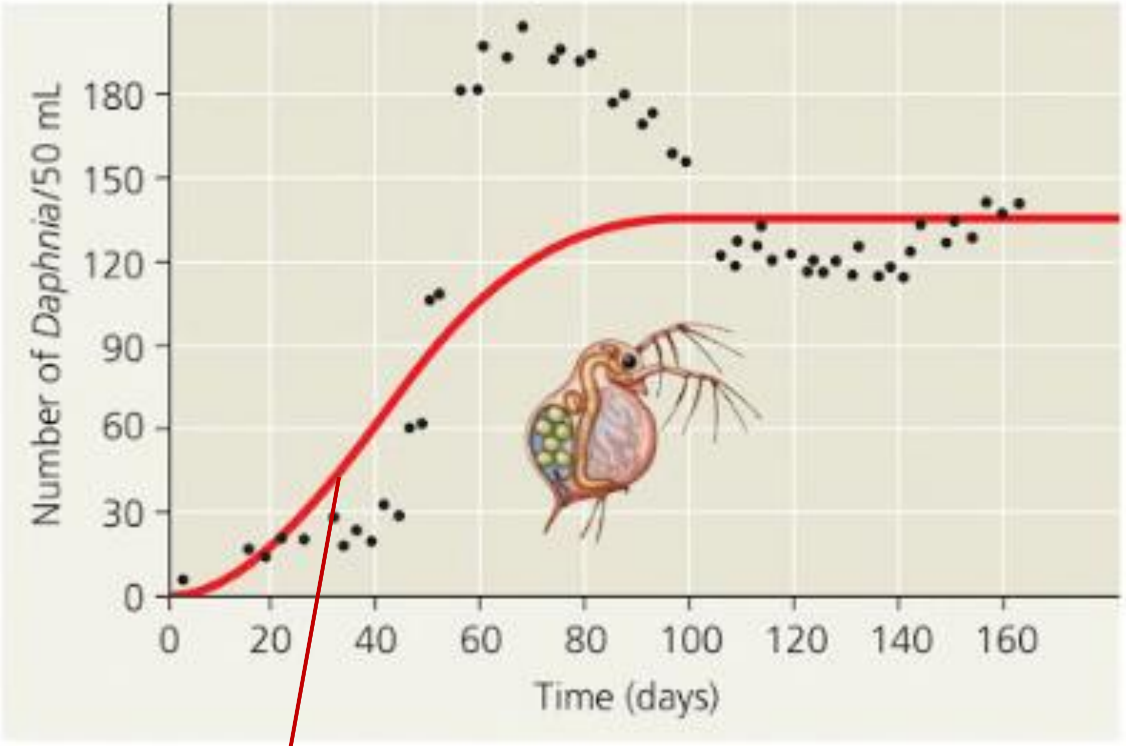
v=velocity

Power tells you how fast a job is done (J / s). The action, on the other h

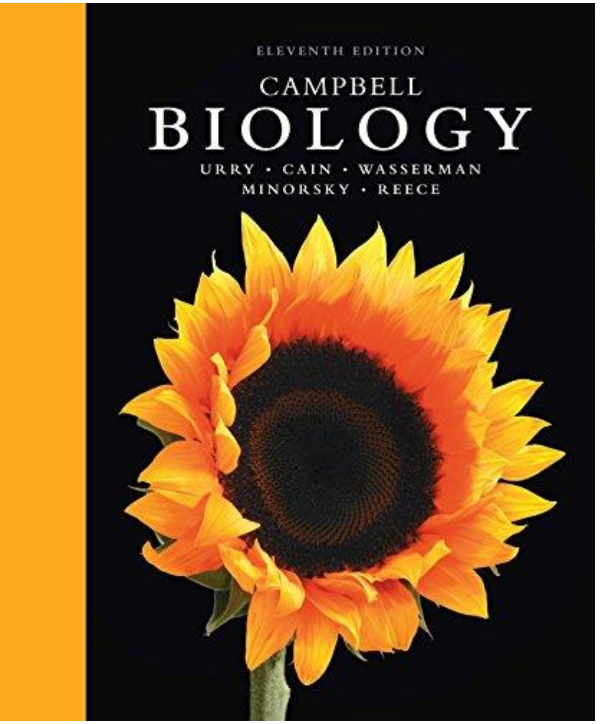
Figure 53.11 How well do these populations fit the logistic growth model? In each graph, the black dots plot the measured growth of the population, and the red curve is the growth predicted by the logistic model.



(a) A *Paramecium* population in the lab. The growth (black dots) of *Paramecium aurelia* in a small culture closely approximates logistic growth (red curve) if the researcher maintains a constant environment.



(b) A *Daphnia* population in the lab. The growth (black dots) of a population of water fleas (*Daphnia*) in a small laboratory culture does not correspond well to the logistic model (red curve). This population overshoots the carrying capacity of its artificial environment before it settles down to an approximately stable population size.



https://www.lacesmagnetschool.org/ourpages/auto/2015/6/3/39944120/Ch53.pdf

File Help

\+ - 100% Fit

Image

Axes

XY

Datasets

Default Dataset

Measurements

Dataset

Axes: XY

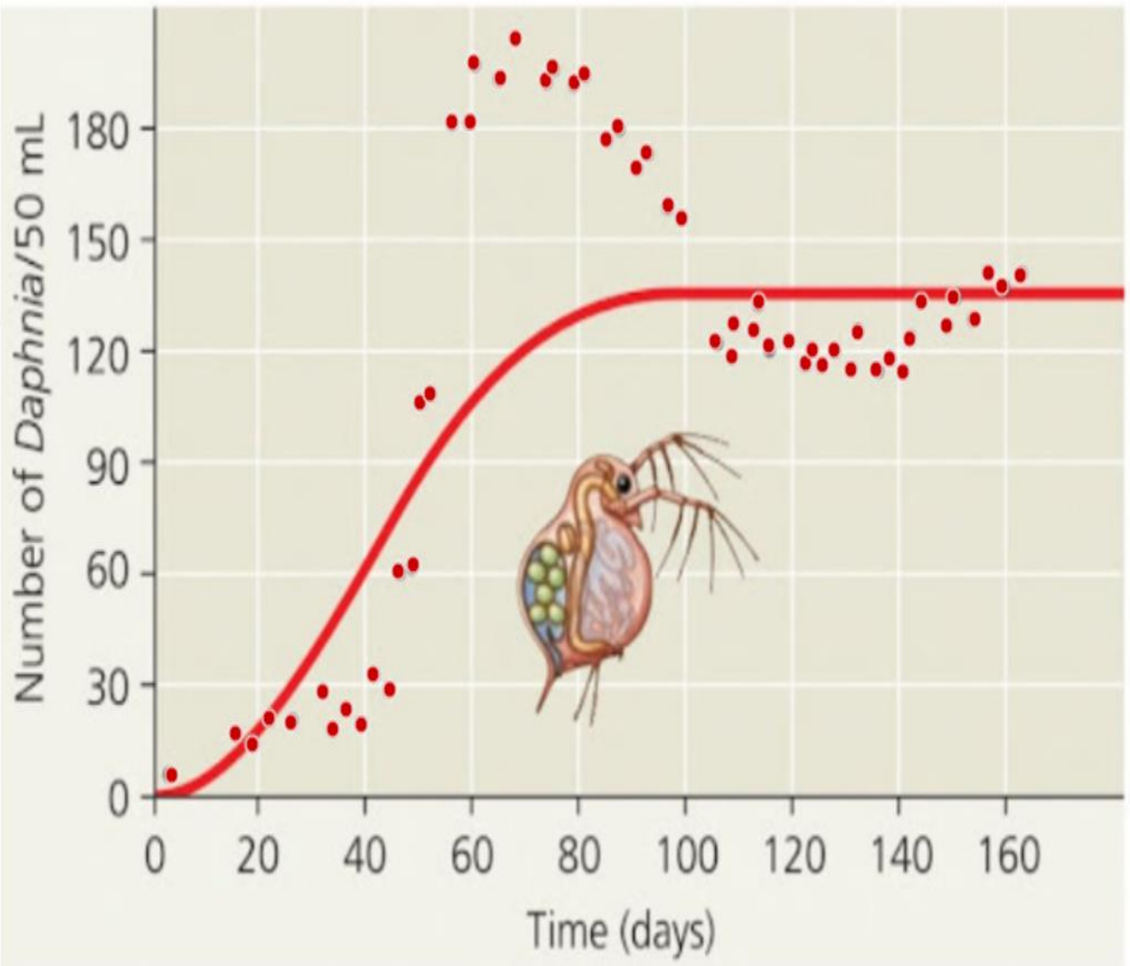
Rename Dataset

Delete Dataset

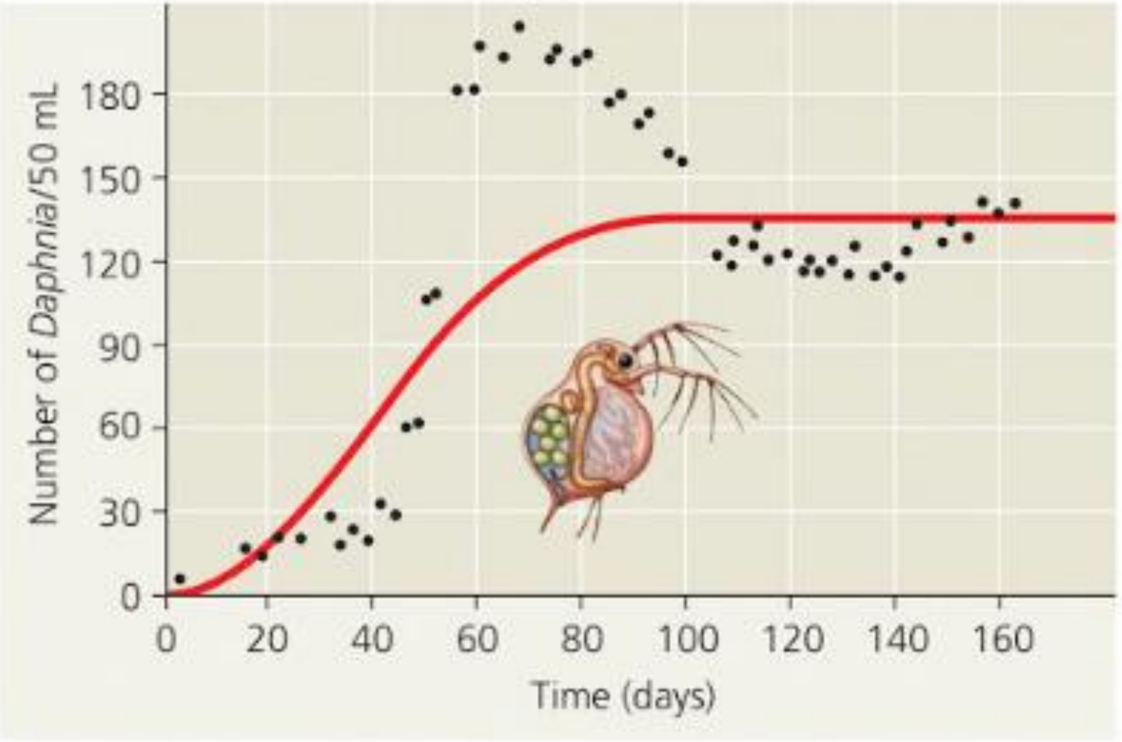
View Data

Clear Data

Data Points: 54



constant environment.



(b) A *Daphnia* population in the lab. The growth (black dots) of a population of water fleas (*Daphnia*) in a small laboratory culture does not correspond well to the logistic model (red curve). This population overshoots the carrying capacity of its artificial environment before it settles down to an approximately stable population size.

Fitting the Triple Logistic Model to Response Data

AIC_c= 239,525 BIC= 254,299

Clear Data Range | HOME | Save | Graphics

Point	Input (x)	Output (y)	Residuals	Expected	Qm
1	3,155819	6,470588	-8,4992	14,9698	4,826
2	15,14793	17,64706	-0,3471	17,9941	0,007
3	18,30375	14,70588	-4,1371	18,843	0,908
4	21,45957	21,76471	2,0522	19,7125	0,214
5	25,56213	20,58824	-0,2877	20,876	0,004
6	31,55819	28,82353	6,1221	22,7014	1,651
10	41,02564	33,52941	4,5379	28,9915	0,71
11	44,18146	29,41176	-8,2360	37,6477	1,802
12	45,75937	61,17647	14,8851	46,2914	4,786
13	48,59961	62,94118	-11,3077	74,2489	1,722
14	49,86193	106,4706	14,3262	92,1444	2,227
15	51,75542	108,8235	-13,1622	121,986	1,42
16	55,85799	181,7647	9,9553	171,809	0,577
17	59,32939	181,7647	-7,0363	188,801	0,262
18	59,96055	197,6471	7,2865	190,361	0,279
19	65,00986	193,5294	-2,4564	195,986	0,031
20	67,8501	204,1176	7,2465	196,871	0,267
21	73,53057	192,9412	-3,9084	196,85	0,078
22	74,7929	196,4706	-0,0626	196,533	2E-05
23	78,89546	192,3529	-2,0584	194,411	0,022
24	80,78895	194,7059	2,0028	192,703	0,021
25	84,89152	177,0588	-9,8217	186,881	0,516
26	87,10059	180,5882	-1,7657	182,354	0,017
27	90,57199	169,4118	-3,8713	173,283	0,086
28	92,46548	173,5294	5,9913	167,538	0,214
29	96,56805	159,4118	4,9836	154,428	0,161
30	99,0927	155,8824	9,0365	146,846	0,556
31	105,4043	122,9412	-9,7942	132,735	0,723
32	108,5602	118,8235	-9,7361	128,56	0,737
33	108,8757	127,6471	-0,5862	128,233	0,003
34	113,6095	133,5294	8,6401	124,889	0,598
35	112,6627	125,8824	0,5244	125,358	0,002
36	115,503	121,7647	-2,4162	124,181	0,047
37	119,2899	122,9412	-0,5101	123,451	0,002
38	122,4458	117,0588	-6,2460	123,305	0,316
39	123,7081	120,5882	-2,7344	123,323	0,061
40	125,6016	116,4706	-6,9365	123,407	0,39
41	127,8107	120,5882	-2,9823	123,57	0,072
42	132,2288	125,2941	1,2699	124,024	0,013
43	130,9665	115,2941	-8,5886	123,883	0,595
44	135,7002	115,2941	-9,1461	124,44	0,672
45	138,2249	118,2353	-6,5194	124,755	0,341
46	140,7495	114,7059	-10,3650	125,071	0,859
47	142,0118	123,5294	-1,6987	125,228	0,023

Sample Statistics

Min Input	3,1558		Min Output	6,47
Max Input	162,8402		Max Output	204,12

Regression

a	b	k	a'	b'	k'	a"	b"	k"	SSE
57,03103059	51,0558377	0,02156751	221,987134	51,0558377	0,37994109	189,232535	94,5003522	0,1547314	2862,7096
30,59256556	38,95670198	0,016283919	25,42810056	0,381381001	0,06480123	38,17630665	25,56002178	0,041921903	*Standard Errors*
1,8642	1,3106	1,3245	8,7300	133,8710	5,8632	4,9568	3,6972	3,6909	*t-Statistics*
0,068823183	0,196649762	0,192035598	P<0.0001	P<0.0001	P<0.0001	P<0.0001	0,000589946	0,00060116	*p-values*
Goodness of Fit (R^2_{adj}) = 98,404%	Qm = 36,1575540146386							Critical Xi^2 =	60,48088658

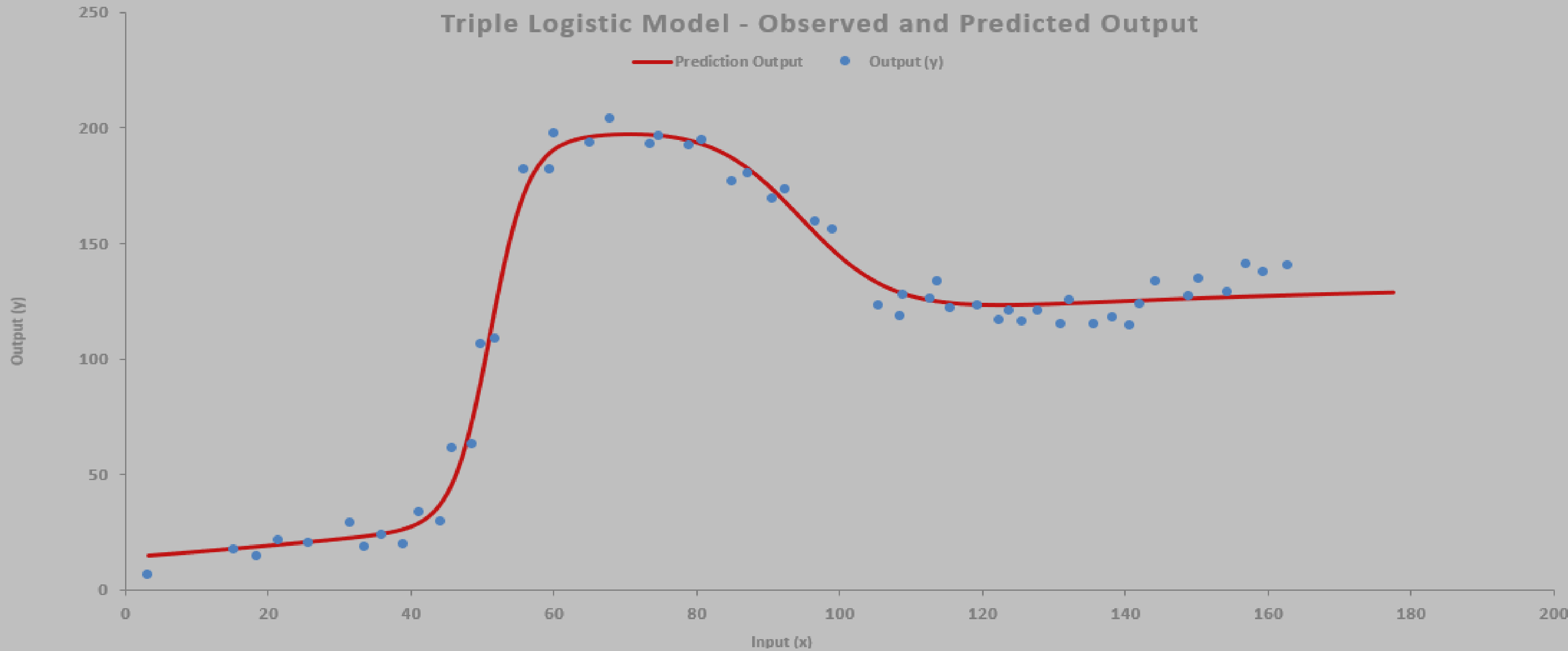
Regression models with Qm>critical Xi^2, indicating inadequate fits, are highlighted in red

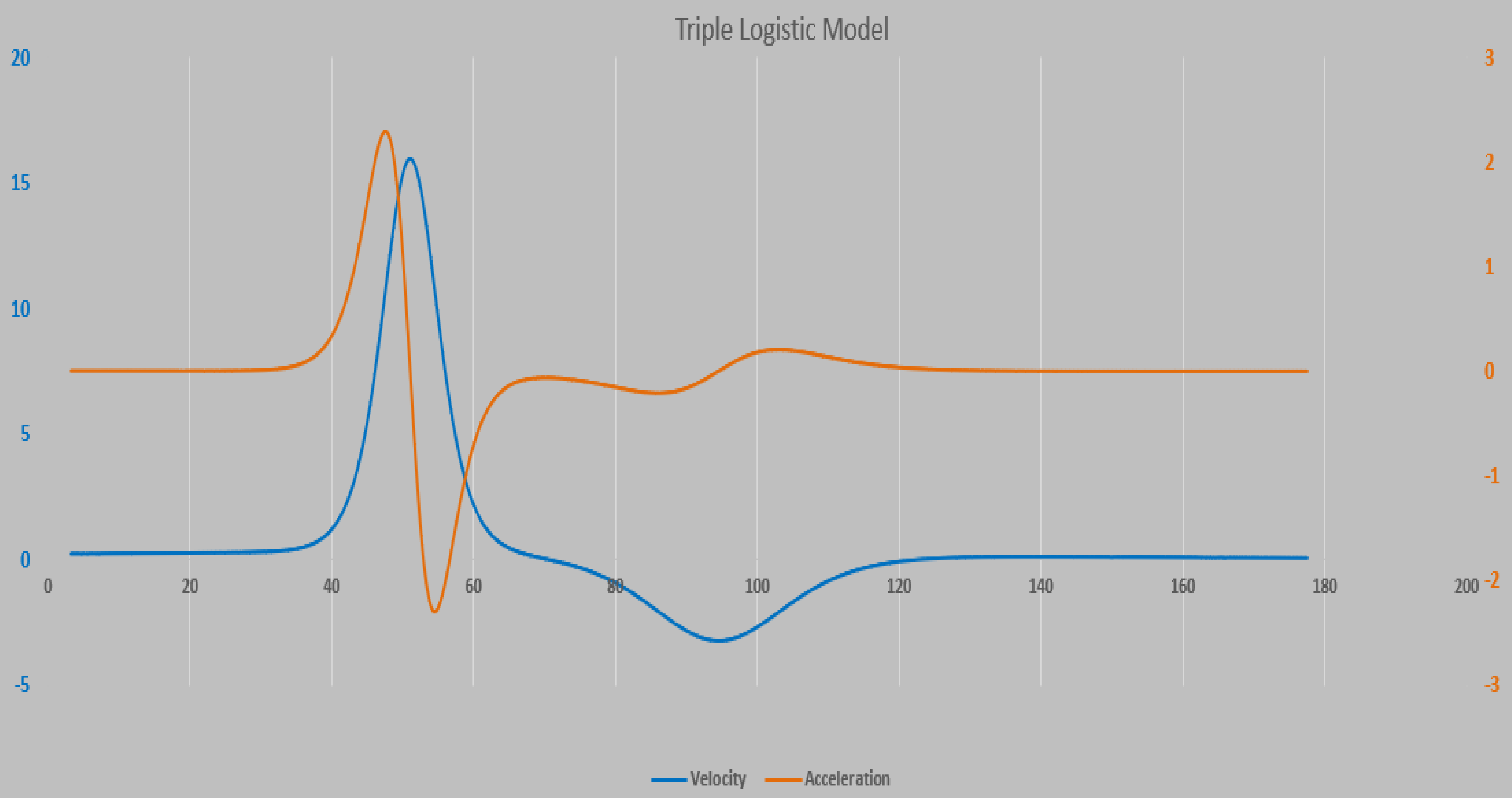
Functional Form

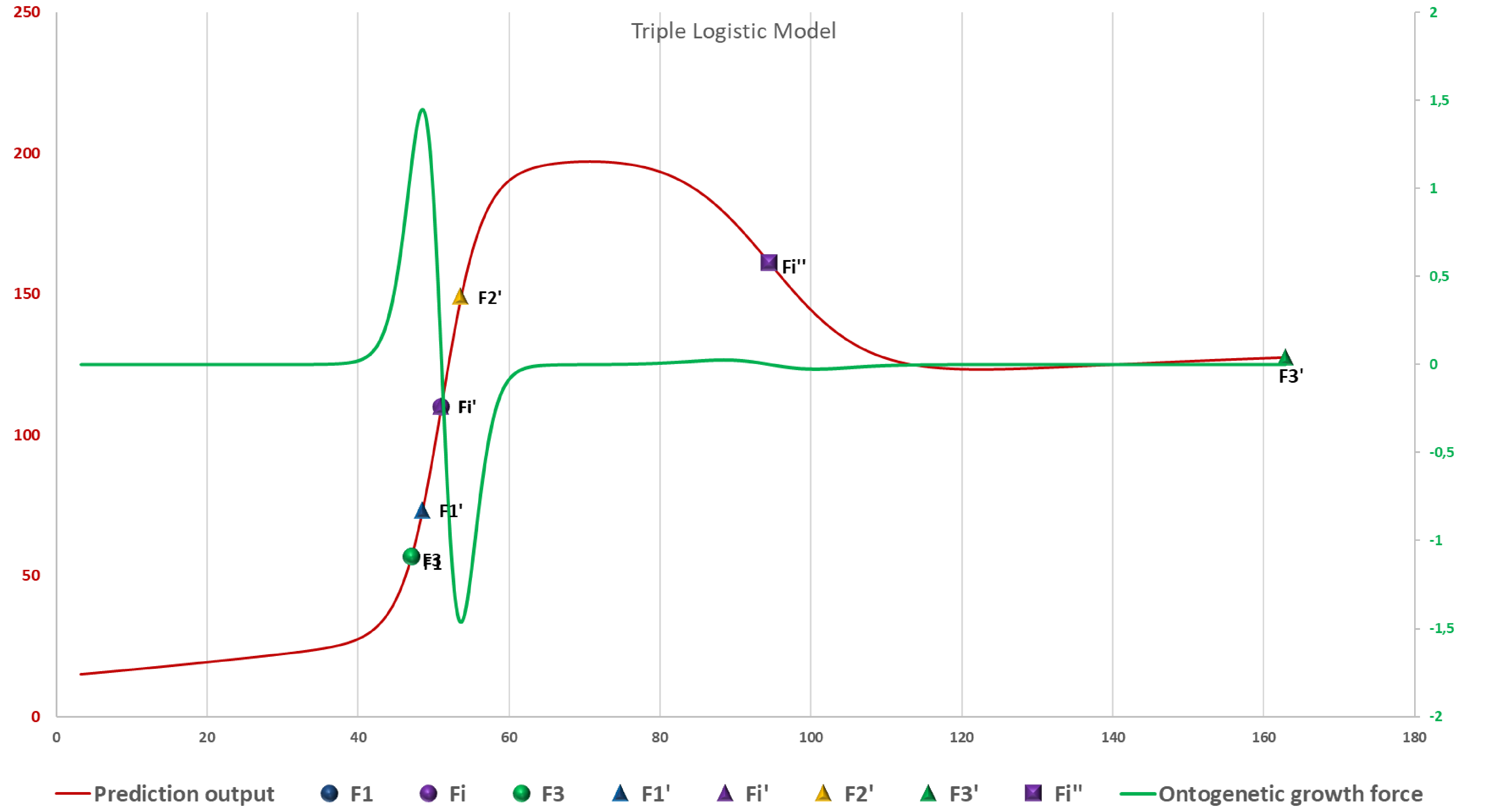
$$y = \frac{a}{1+e^{k(b-x)}} + \frac{a'-a}{1+e^{k'(b'-x)}} + \frac{a''-a'-a}{1+e^{k''(b''-x)}}$$

a'-a= 164,9561037 221,9871342

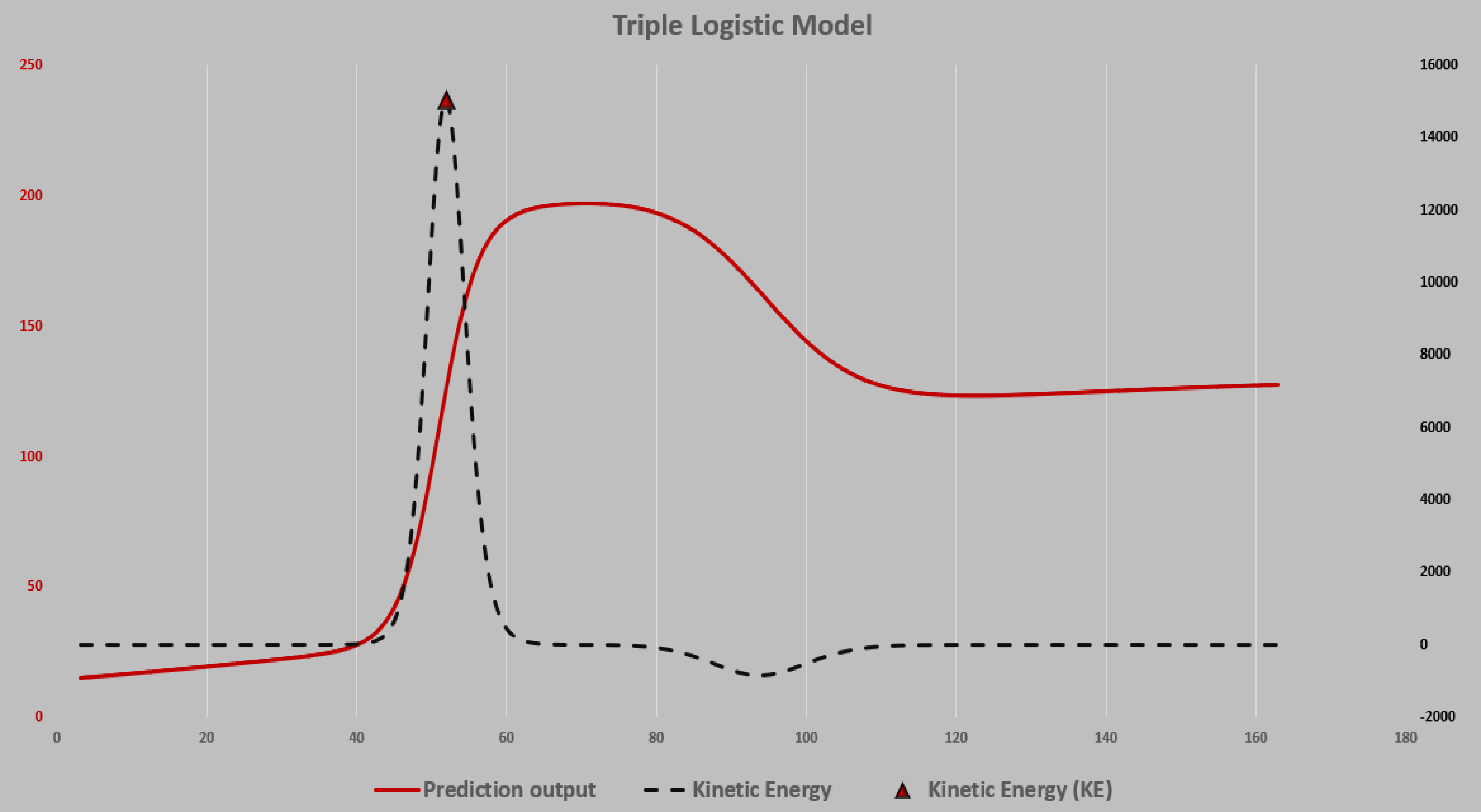
a''-a'-a= -89,78563034 132,2015039

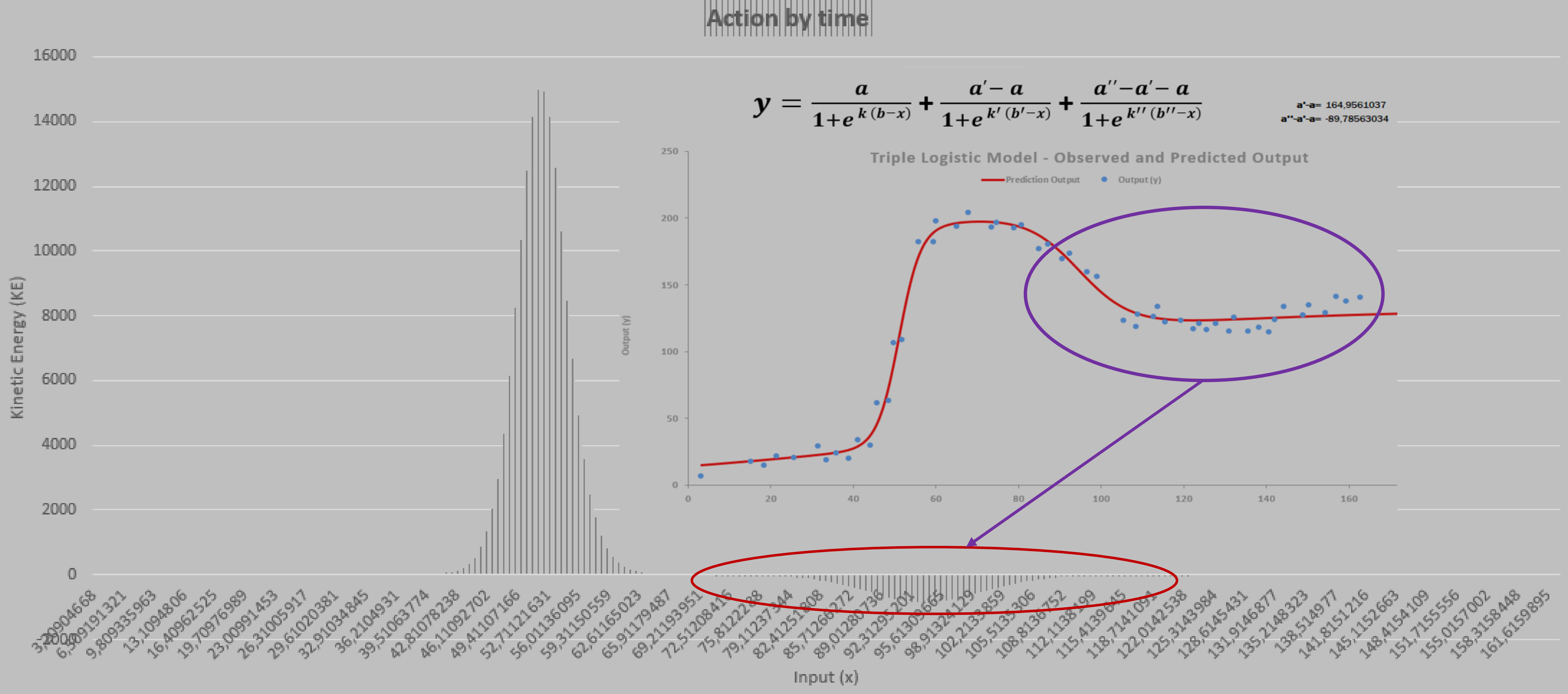



Triple Logistic Model
20
15
10
5
0
-5
3
2
1
0
-1
-2
-3
0
20
40
60
80
100
120
140
160
180
200
Velocity
Acceleration



Triple Logistic Model
250
200
150
100
50
0
2
1,5
1
0,5
0
-0,5
-1
-1,5
-2
0
20
40
60
80
100
120
140
160
180
F2'
Fi''
Fi'
F1'
F3
F1
F3'
Prediction output
F1
Fi
F3
F1'
Fi'
F2'
F3'
Fi''
Ontogenetic growth force


Triple Logistic Model
250
200
150
100
50
0
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
0
20
40
60
80
100
120
140
160
180
Prediction output
Kinetic Energy
Kinetic Energy (KE)



	Kinetic Energy (KE)		Input	Output
$KE_{maximum}$ =	15.043,08	1,5043E+04	51,913	124,444
			By Input	
ACTION =	1.639.924,10	1,6399E+06	**162,893**	127,513

Theory of growth based on fi

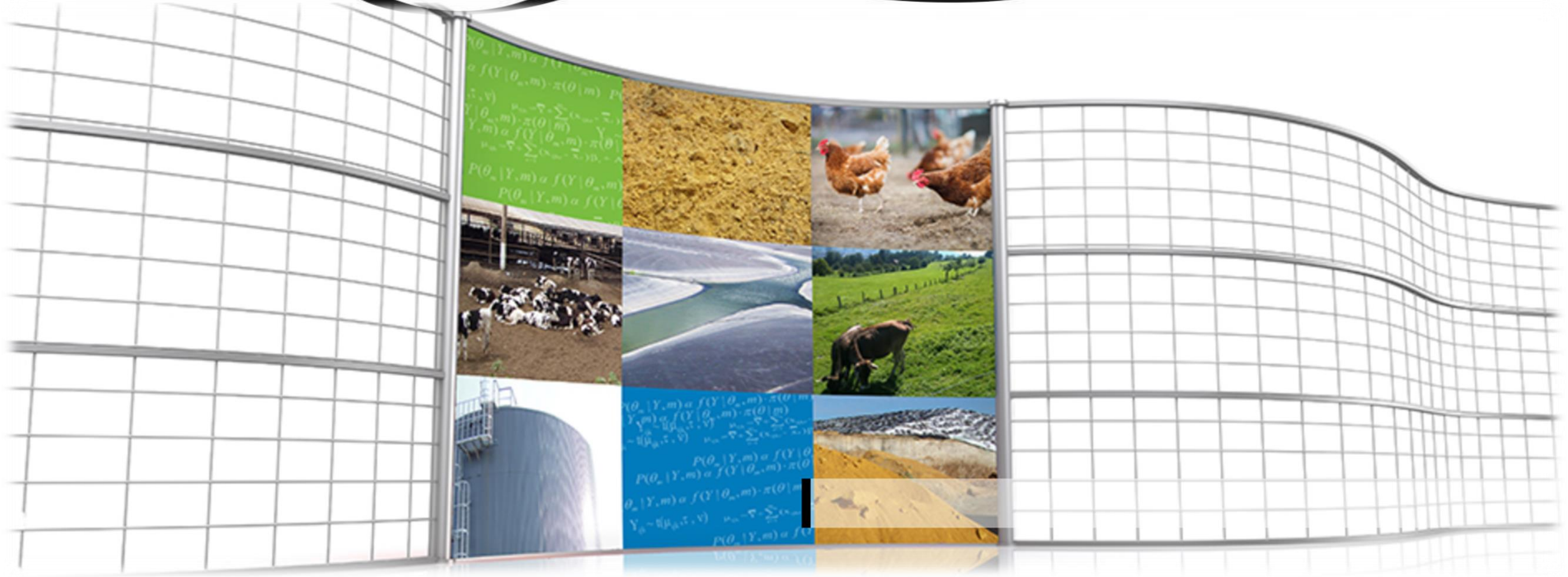
$$KE=m*v^2/2$$

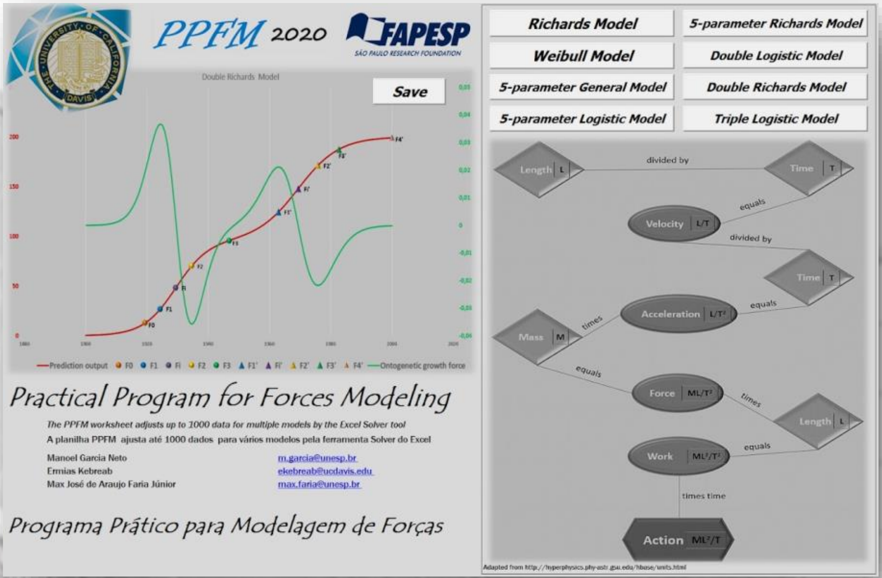
Power tells you how fast a job is done (

Summary

- Models of growth: simply mathematical descriptions of growth trajectories;
- The growth function is necessary, but not sufficient condition for to understand the growth process;
- First principle of energy: balance of energy between production of new biomass and maintenance of existing biomass;
- Action: allows to complete the understanding of the growth models.

Thank you





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