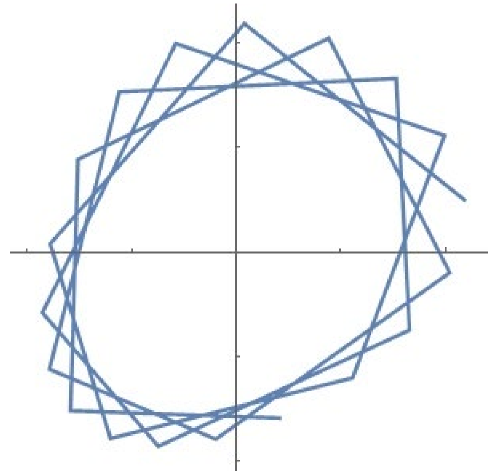
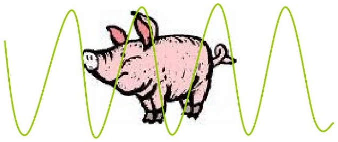


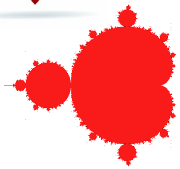
OSCILLATORS

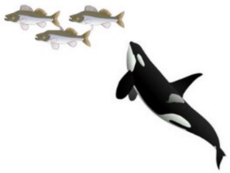
mechanisms of oscillating behaviours

by Loe Feijs
professor of Industrial Design at TU/e
for course Complex Adaptive Systems 2020

TYPES OF OSCILLATIONS

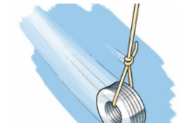


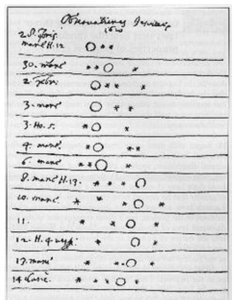




- free systems
- tuned oscillators
- phase shift oscillators
- relaxation oscillators
- chaotic oscillators
- predator-prey systems
- forcing
- modulation
- synchronisation

Sources: www.scientificamerican.com/, www.ldoceonline.com, www.slideshare.net/Carolederks/samenvatting-belevenis-economie-presentation, rheingoldheavy.com/arduino-from-scratch-part-9-16mhz-crystal-oscillator, www.biologycorner.com/worksheets/predatorsim.html

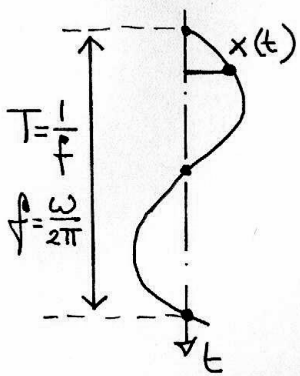
FREE SYSTEMS 

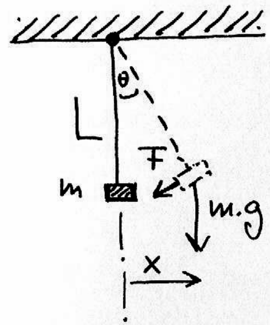


- Jupiter, Io, Europa, Ganymedes and Callisto
- The earth and the moon
- The sun and the earth
- Any pendulum
- The earth

Gallileo’s note sheet,Video by Steve Jones of Foucault's Pendulum at the Pantheon in Pa

FREE SYSTEMS





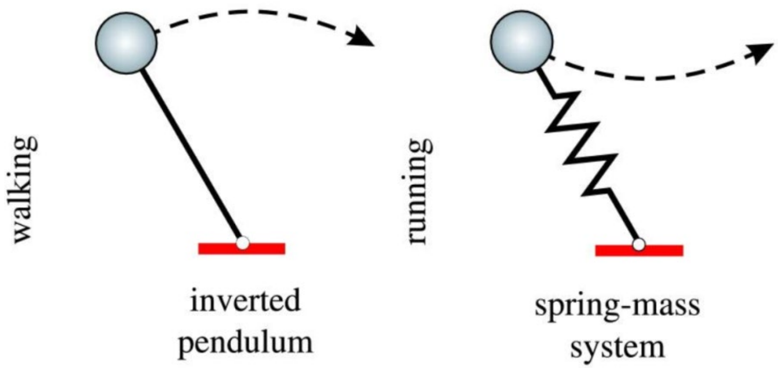
$$\left.\begin{array}{l} F = -m.g.\sin\theta \approx -m.g.\frac{x}{L} \\ F = m.\ddot{x} \quad \text{(Newton)} \end{array}\right\} \begin{array}{l} -mg\frac{x}{L} \\ = m\ddot{x} \end{array}$$

$$\boxed{-\ddot{x} = \frac{g}{L}x}$$

try $x(t) = \sin\omega t$, so $\dot{x}(t) = \omega\cos\omega t$, $\ddot{x}(t) = -\omega^2\sin\omega t$

$-\omega^2\sin\omega t \overset{?}{=} \frac{g}{L}\sin\omega t$ YES if $\omega = \sqrt{\frac{g}{L}}$

FREE SYSTEMS



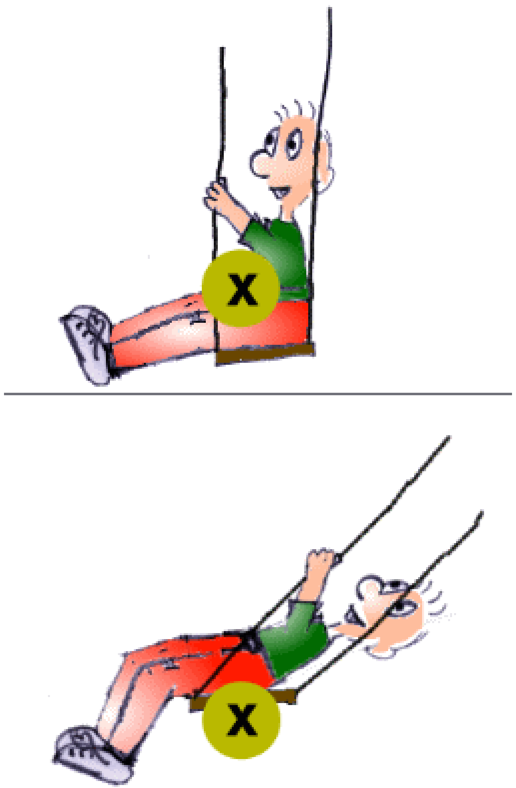
Standard conceptual models of legged locomotion and their predictive power with respect to walking and running dynamics. The inverted pendulum and the spring–mass system are the standard models for walking and running.

Source: Geyer, Hartmut, Andre Seyfarth, and Reinhard Blickhan. “Compliant Leg Behaviour Explains Basic Dynamics of Walking and Running.” Proceedings of the Royal Society B: Biological Sciences 273.1603 (2006): 2861–2867. PMC. Web. 16 May 2018.

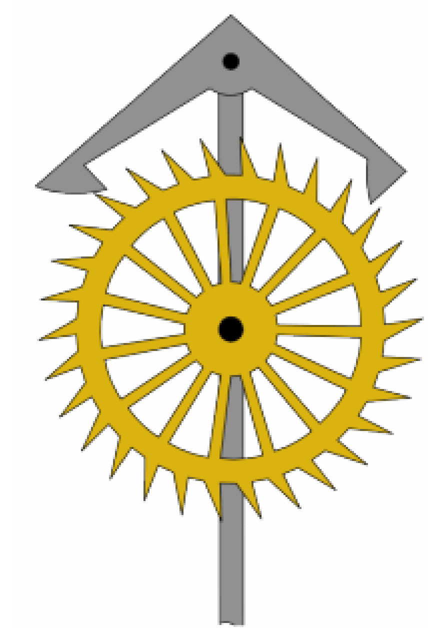
Passive walker,

Source: www.space-eight.com

TUNED OSCILLATORS



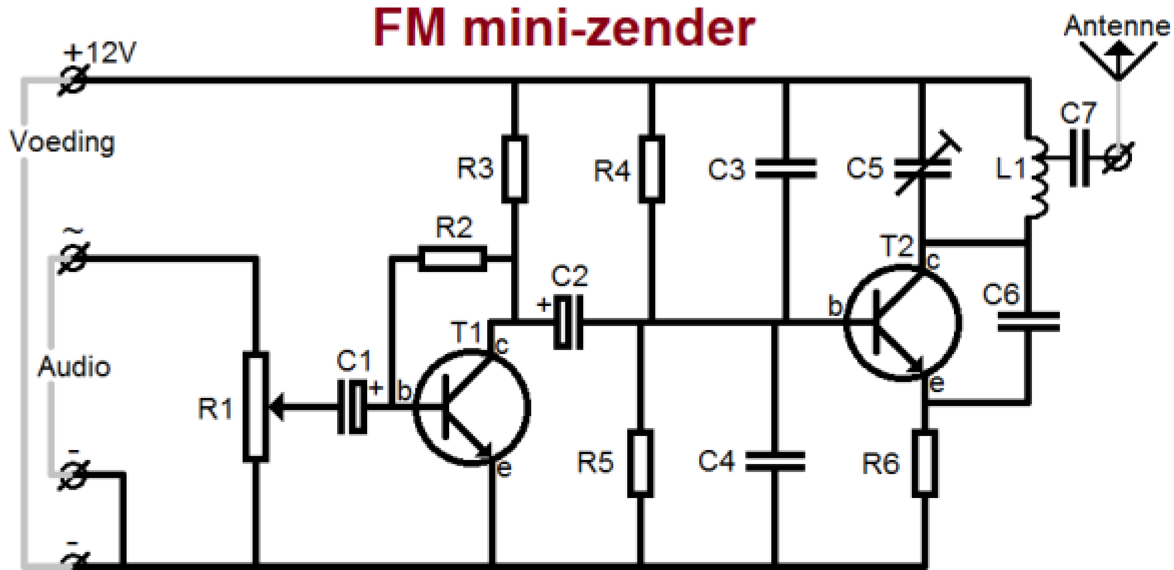
Supplying energy while pumping the swing by lifting and lowering the center of gravity (Wikipedia: Energiezufuhr beim Schaukeln durch Heben und Senken des Schwerpunkts)



Ancor escapement

Source:commons.wikimedia.org/w/index.php?curid=3056978, Anchor escapement animation by Chetvorno, Wikimedia

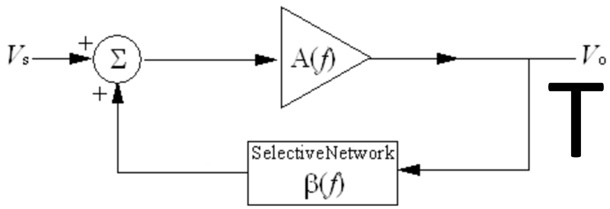
TUNED OSCILLATORS



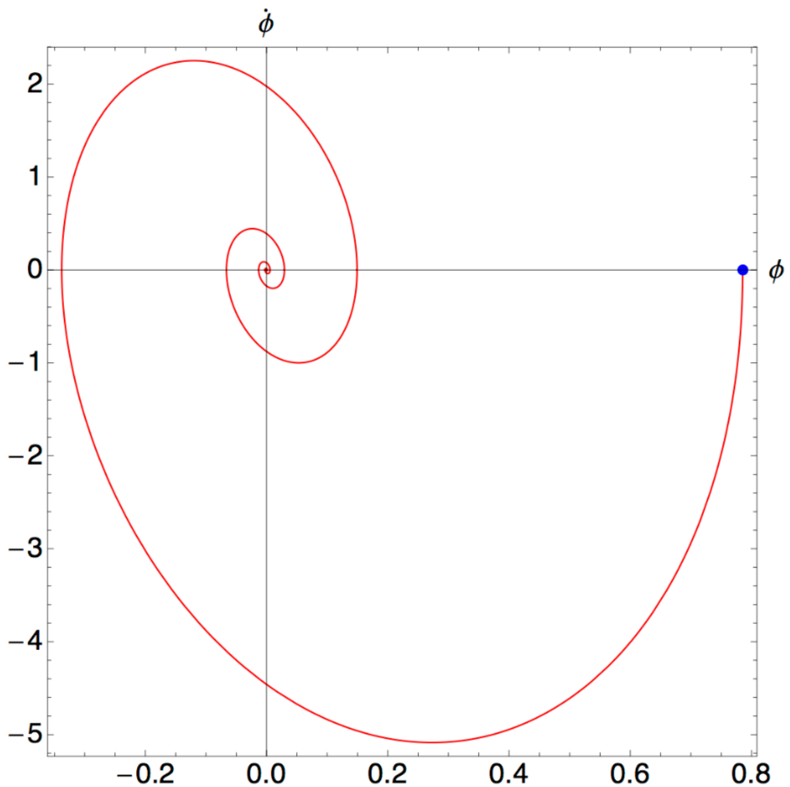
De benodigde onderdelen:

T1 = BC547	C1 = 10 uF
T2 = 2N2219A	C2 = 10 uF
R1 = 22 KΩ Potmeter	C3 = 470 pF
R2 = 120 KΩ	C4 = 470 pF
R3 = 4700 Ω	C5 = 30 pF Trimmer
R4 = 10 KΩ	C6 = 3 pF
R5 = 10 KΩ	C7 = 10 pF
R6 = 100 Ω	L1 = 4 windingen, doorsnede windingen 6 mm, wikkeldraad 0,8 mm², aftaking na de eerste winding.

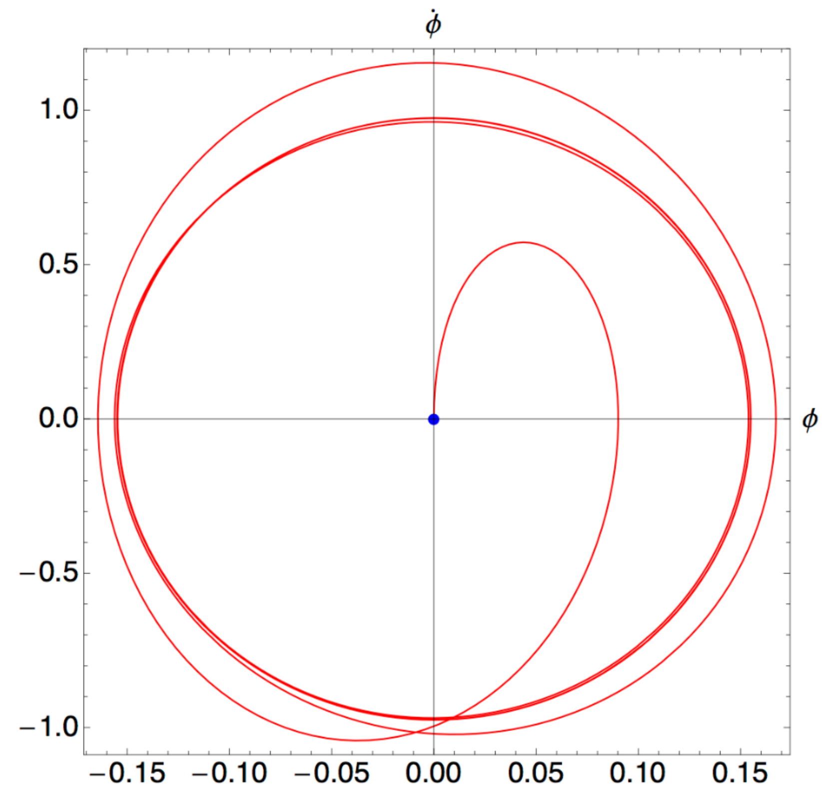
http://www.babylona.nl/Geschiedenis.htm



TUNED OSCILLATORS



Phase pace behaviour of damped swing

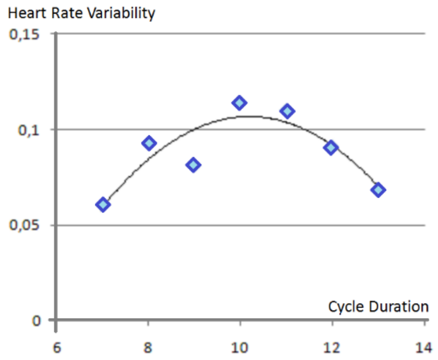


Limit cycle of swing with positive feedback

Sources: Ethan Neil, lecture notes Physics 3210, Fall 2015, www.colorado.edu and 06103104HKN, gnindia.dronacharya.info/

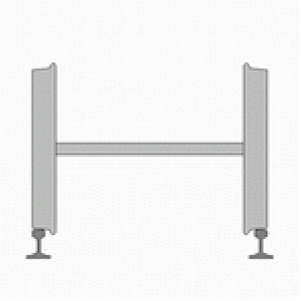
TUNED OSCILLATORS

Mayer waves (10 seconds waves in blood pressure)

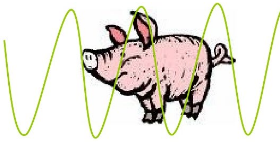


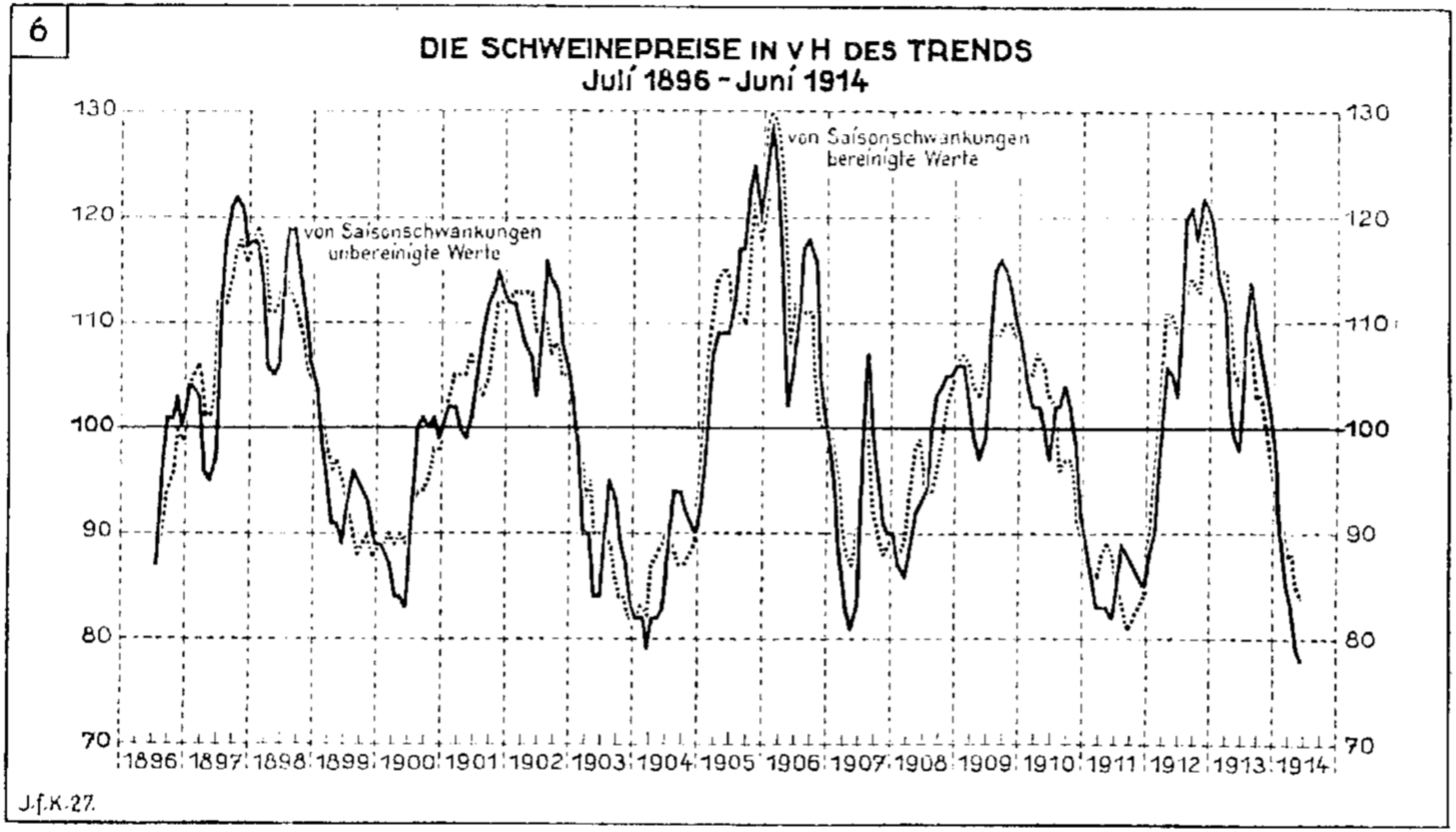
Feijs, L., Langereis, G., & Van Boxtel, G. (2010). Designing for heart rate and breathing movements. *Design and semantics of form and movement, 57*.

Hunting oscillation in railway tracks:
https://en.wikipedia.org/wiki/Hunting_oscillation



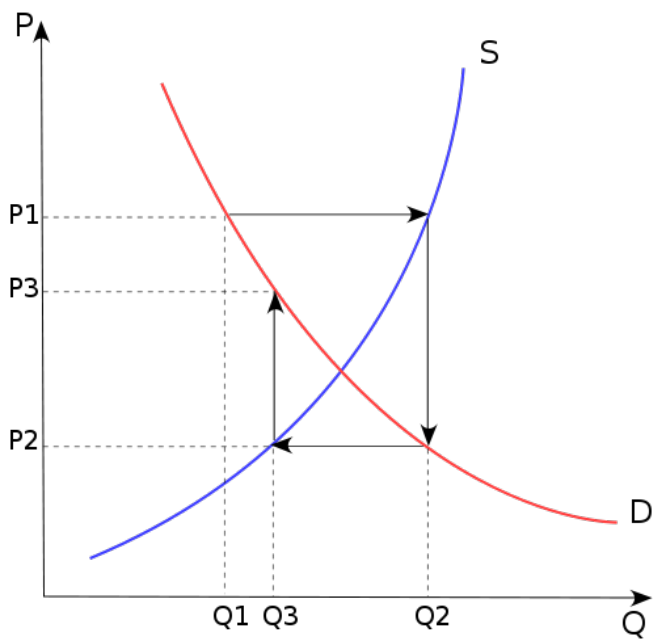
PHASE SHIFT OSCILLATORS

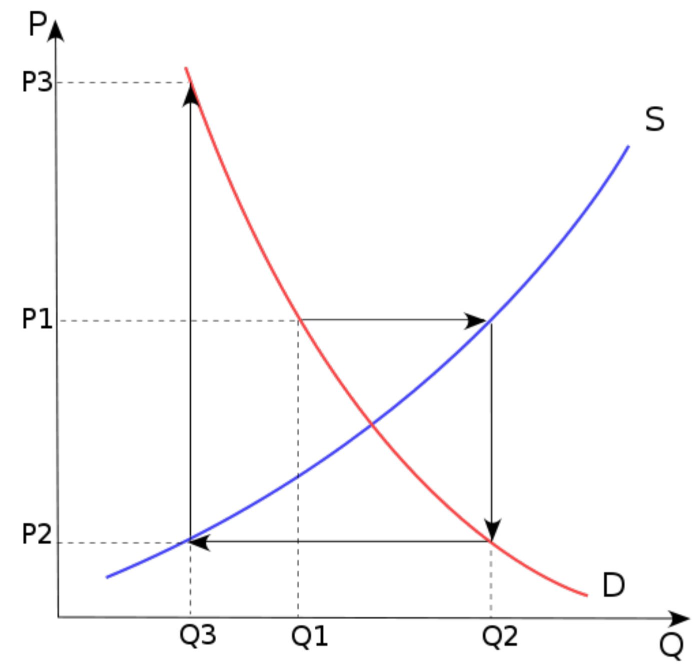




Picture credit: Arthur Hanau, „Die Prognose der Schweinepreise", Sonderheft 7, Institut für Konjunkturforschung, 1928.

PHASE SHIFT OSCILLATORS

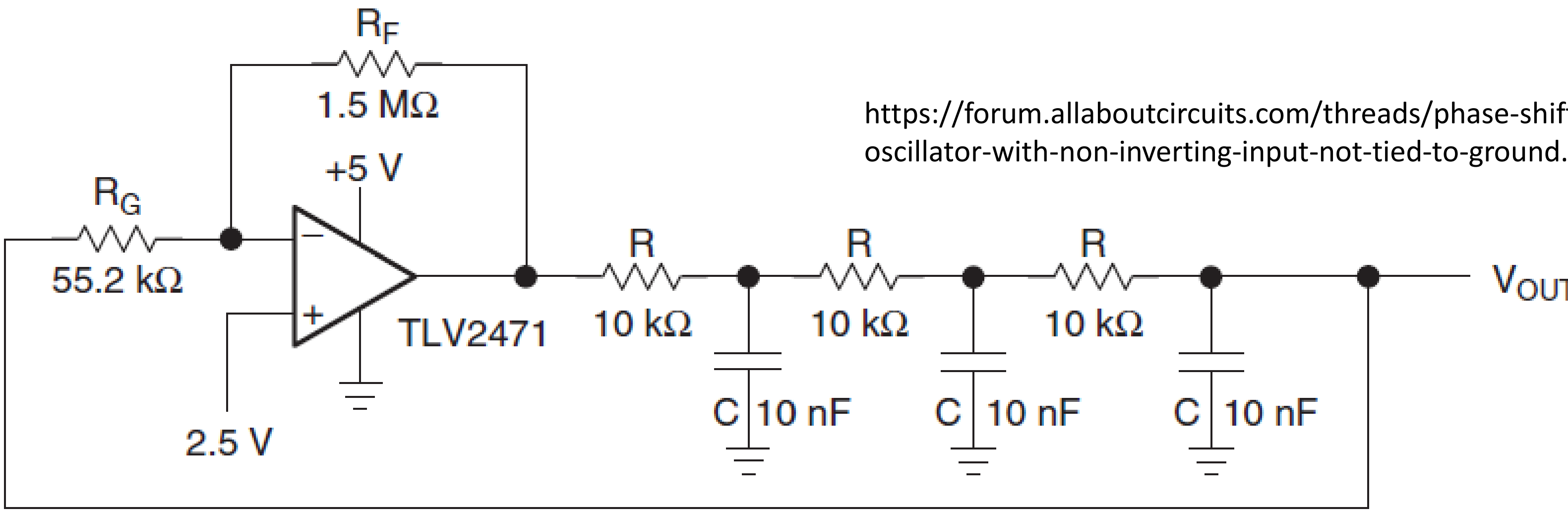




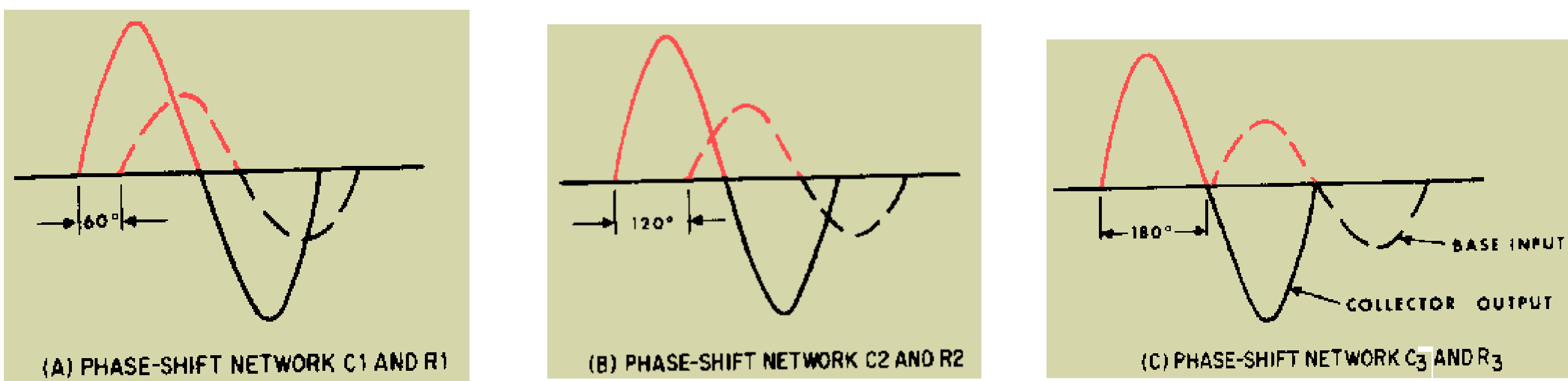
Cobweb-theory: Supply (S) and Demand (D) affecting prizes $P_{1,2,3}$ and Quantities $Q_{1,2,3}$

By Cobweb_theory.png: by Rinconsoleao at en.wikipediaSupply-and-demand

PHASE SHIFT OSCILLATORS



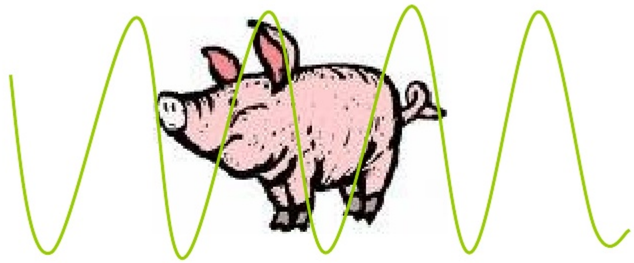
https://forum.allaboutcircuits.com/threads/phase-shift-oscillator-with-non-inverting-input-not-tied-to-ground.82055/



Source: http://www.tpub.com/neets/book9/35e.htm

PHASE SHIFT OSCILLATORS

Het lot van commodities: de varkenscyclus



Varkenscyclus:
Stel dat de prijs van varkensvlees op een moment hoog is. Veel landbouwers besluiten dan varkens te gaan houden. Als de varkens na een paar jaar op de markt worden aangeboden, is de opbrengst laag door het grote aanbod. Veel landbouwers besluiten dan weer te stoppen met varkens. In de daarop volgende periode is de varkensprijs weer hoog door het kleine aanbod.

Süddeutsche Zeitung

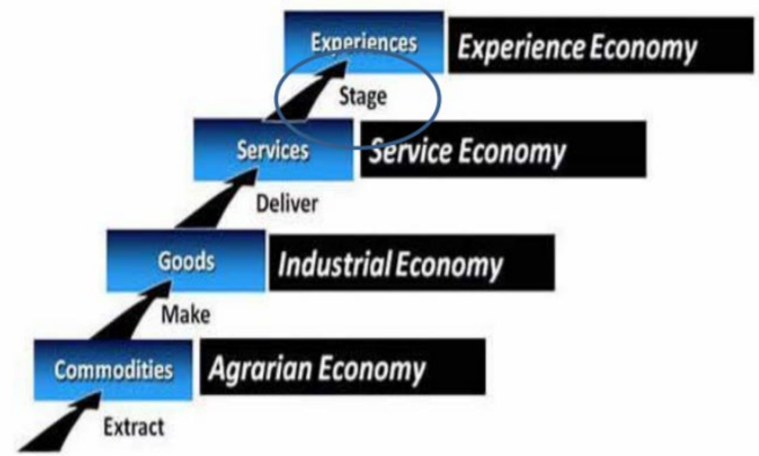
6. Dezember 2016, 18:53 Uhr Rohstoffmärkte

Edles Metall

Zink ist innerhalb eines Jahres um 80 Prozent teurer geworden. Schuld sind nicht nur Spekulationen. Als die Preise noch niedrig waren, haben Bergbaufirmen ihre Minen geschlossen. Dann zog plötzlich die Nachfrage an.

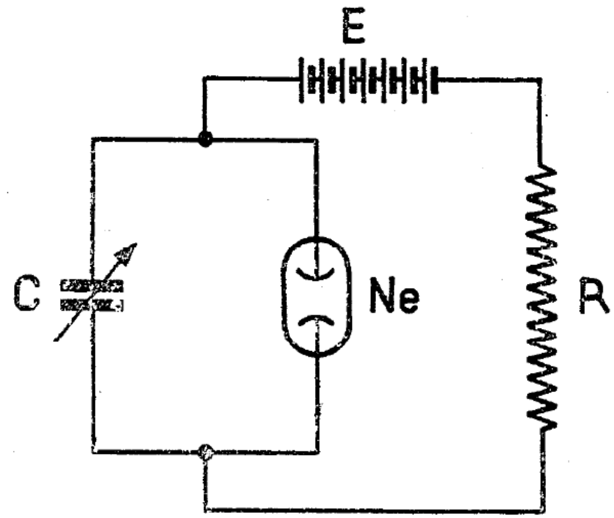
3.2. De belangstelling voor de opleiding Scheikunde

De instroom in de negen wetenschappelijke opleidingen Scheikunde/Scheikundige Technologie/ Moleculaire Wetenschappen die Nederland rijk is, lijkt net als vele andere opleidingen sterk onderhevig aan de varkenscyclus.
Na zeer grote belangstelling van studenten voor de opleidingen in de jaren zeventig van de vorige eeuw, is deze, door verminderde vraag naar chemici, begin jaren tachtig teruggelopen, gevolgd door een stijging van de vraag en daarmee van de instroom aan het einde van de jaren tachtig en begin jaren negentig, waarna een zeer sterke daling is ingezet. Inmiddels lijkt het dieptepunt alweer voorbij te zijn. De belangstelling voor bètawetenschappen, evenals de vraag naar afgestudeerden in de bètawetenschappen in het algemeen, lijkt, ook internationaal, weer toegenomen. Bij de opleidingen die de commissie heeft bezocht is deze trend ook waar te nemen. Op enkele opleidingen na is de neergaande studenteninstroom in 2006 omgebogen naar een vergrote belangstelling. Een trend, die naar de commissie hoopt, nog enige jaren door zal zetten. De arbeidsmarkt voor scheikundigen is erg goed, er is veel vraag naar afgestudeerde scheikundigen en scheikundig technologen. Afgestudeerde masterstudenten vinden vrij gemakkelijk een baan.



www.slideshare.net/Carolederks/samenvatting-belevenis-economie-presentation, ExBased project: the experience economy, QUANU, id_2184_rapport UU wo-ba Scheikunde.pdf, 2007

RELAXATION OSCILLATORS



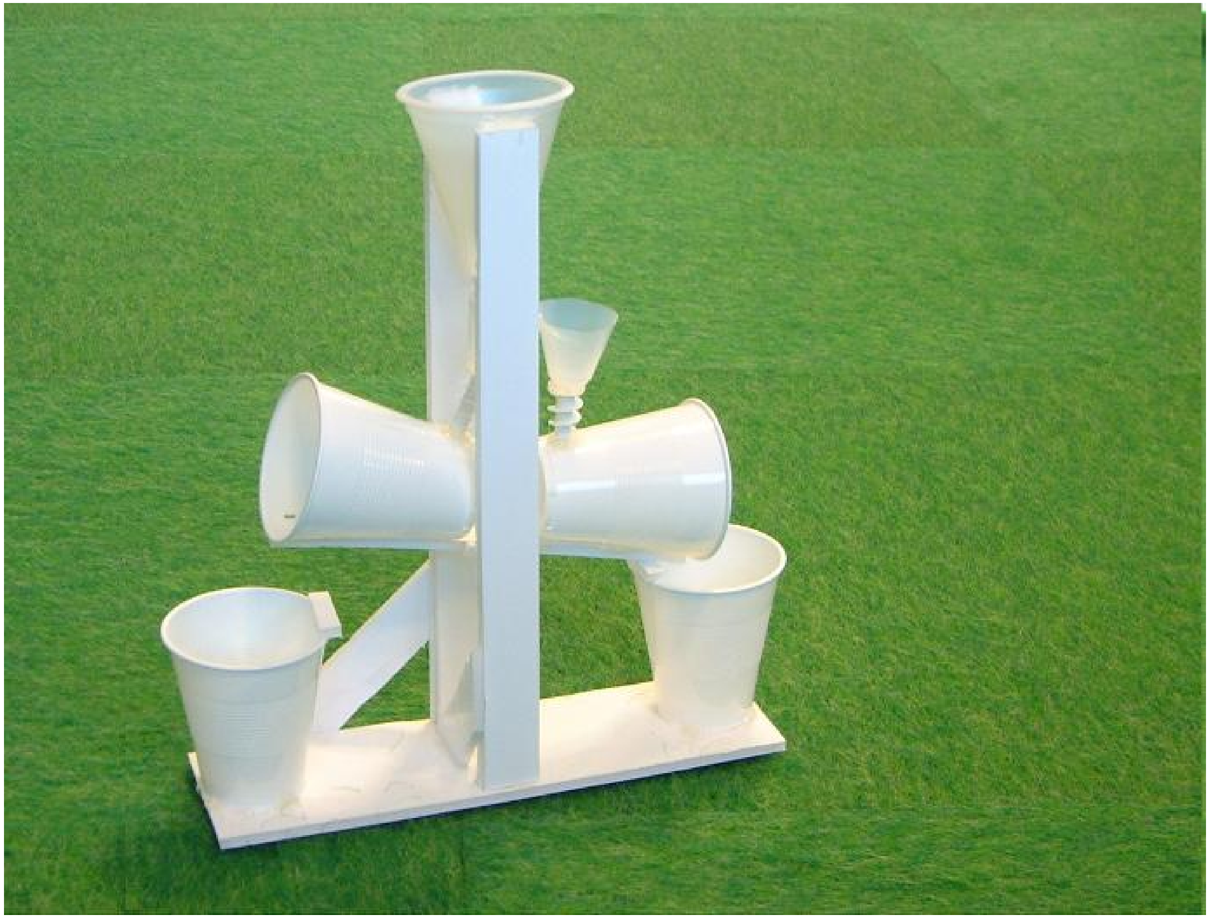
A system capable of producing relaxation oscillations. It consists of a neon lamp Ne, a condenser C of approximately 1 microfarad, a resistance R of the order of 1 megohm, and a battery of about 180 volt.

VAN DER POL, Balth; VAN DER MARK, Jan. LXXII. The heartbeat considered as a relaxation oscillation, and an electrical model of the heart. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, 1928, 6.38: 763-775.

RELAXATION OSCILLATORS

Van der Pol: Some instances of typical relaxation oscillations are: the aeolian harp, a pneumatic hammer, the scratching noise of a knife on a plate, the waving of a flag in the wind, the humming noise sometimes made by a water-tap, the squeaking of a door, the multivibrator of Abraham and Bloch, the tetrode multivibrator, the periodic sparks obtained from a Wimshurst machine, the Wehmelt interrupter, the intermittent discharge of a condensor through a neon tube, the periodic re-occurrence of epidemics and of economical crises, the periodic density of an even number of species of animals living together, and one species serving as food for the other, the sleeping of flowers, the periodic re-occurrence of showers behind a depression, the shivering from cold, menstruations, and finally the beating of the heart.

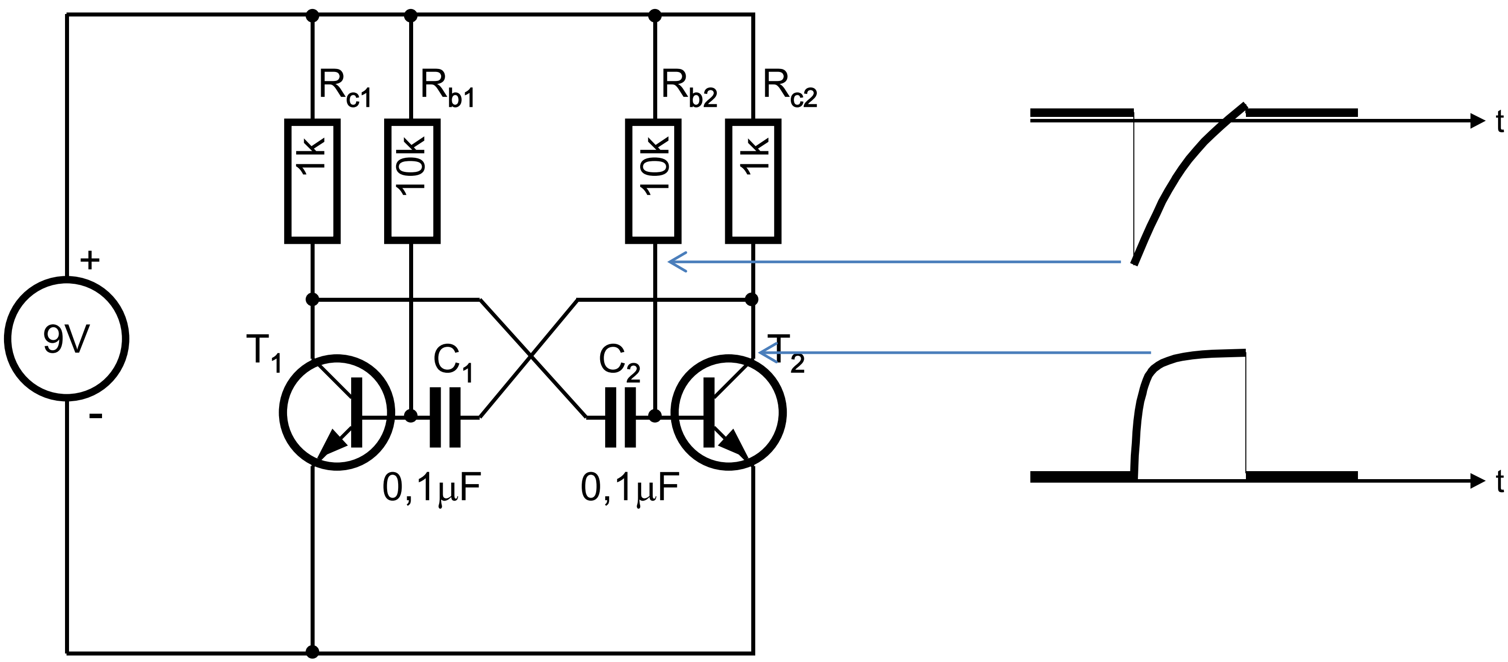
RELAXATION OSCILLATORS



A-stable multivibrator AMV with coffee-cups

Source: www.idemployee.id.tue.nl/l.m.g.feijs/amv.doc

RELAXATION OSCILLATORS



A-stable multivibrator
AMV with two transistors

Source: www.idemployee.id.tue.nl/l.m.g.feijs/amv.doc,
www.elektronicaforum.nl/astabiele-mutivibrator-t16888.html

RELAXATION OSCILLATORS

A less controlled emotion-focused coping activity is what we call an 'emotional outburst'. Outbursts occur when individuals feel overwhelmed by a situation, when emotional tension is too high and individuals can't help but "explode". This can take the form of honking while driving the car, swearing when sitting in the office, banging one's fist on the table or other. It is a relatively short event (say, less than 5 seconds). This approach is dysfunctional in the sense that it might be bad for the individual's environment or detrimental for the reputation of the perpetrator. This will be modeled further below by fixed utility costs. At the same time, however, emotional outbursts also have a functional side as they reduce tension. Denoting the instant before an emotional outburst by τ_{i-}, the effect of an outburst is to reduce tension by a fixed amount $\Delta > 0$,

$$W(\tau_i) = W(\tau_{i-}) - \Delta. \quad (4)$$

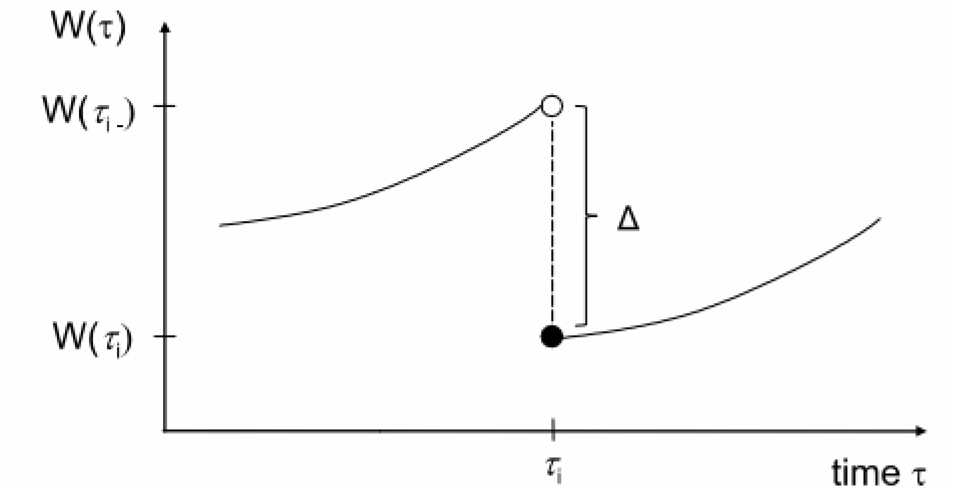
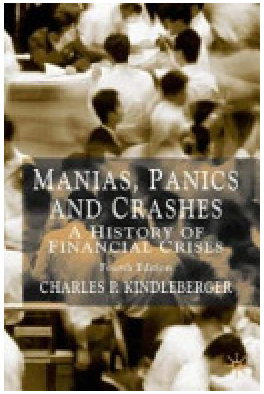


Figure 1 *The effect of an emotional outburst on stress $W(t)$*

Source: Klaus Wälde, Stress and Coping - An Economic Approach, Johannes-Gutenberg University Mainz, www.waelde.com/pdf/Waelde_Stress_and_Coping.pdf



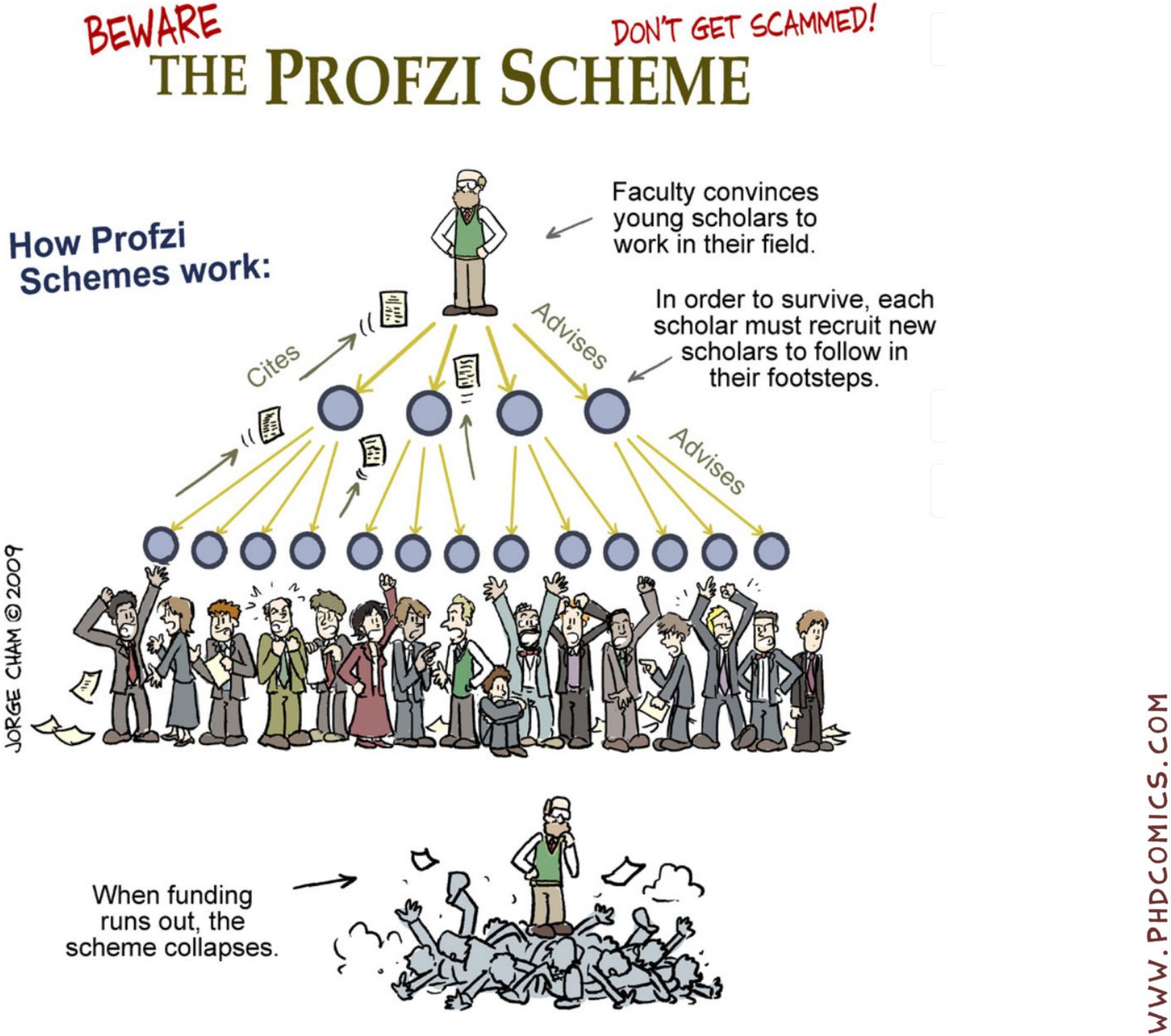
Chain letters: individuals receive a letter asking them to send $1 (or $10 or $100) to the name at the top of the pyramid and to send the same letter to five friends or acquaintances within five days; the promise is that within thirty days you will receive $64 for each $1 'investment.'

Ponzi schemes: someone promises to pay an interest rate of 30 or 40 or 50 percent a month; the entrepreneurs that develop these schemes always claim they have discovered a new secret formula so they can earn these high rates of return. They make the promised interest payments for the first few months with the money received from their new customers attracted by the promised high rates of return.

Pyramid schemes: sharing of commission incomes from the sale of securities or cosmetics or food supplements by those who actually make the sales to those who have recruited them to become sales personnel.

Bubbles: purchasing an asset, usually real estate or a security, not because of the rate of return on the investment but in anticipation that the asset or security can be sold to someone else at an even higher price.

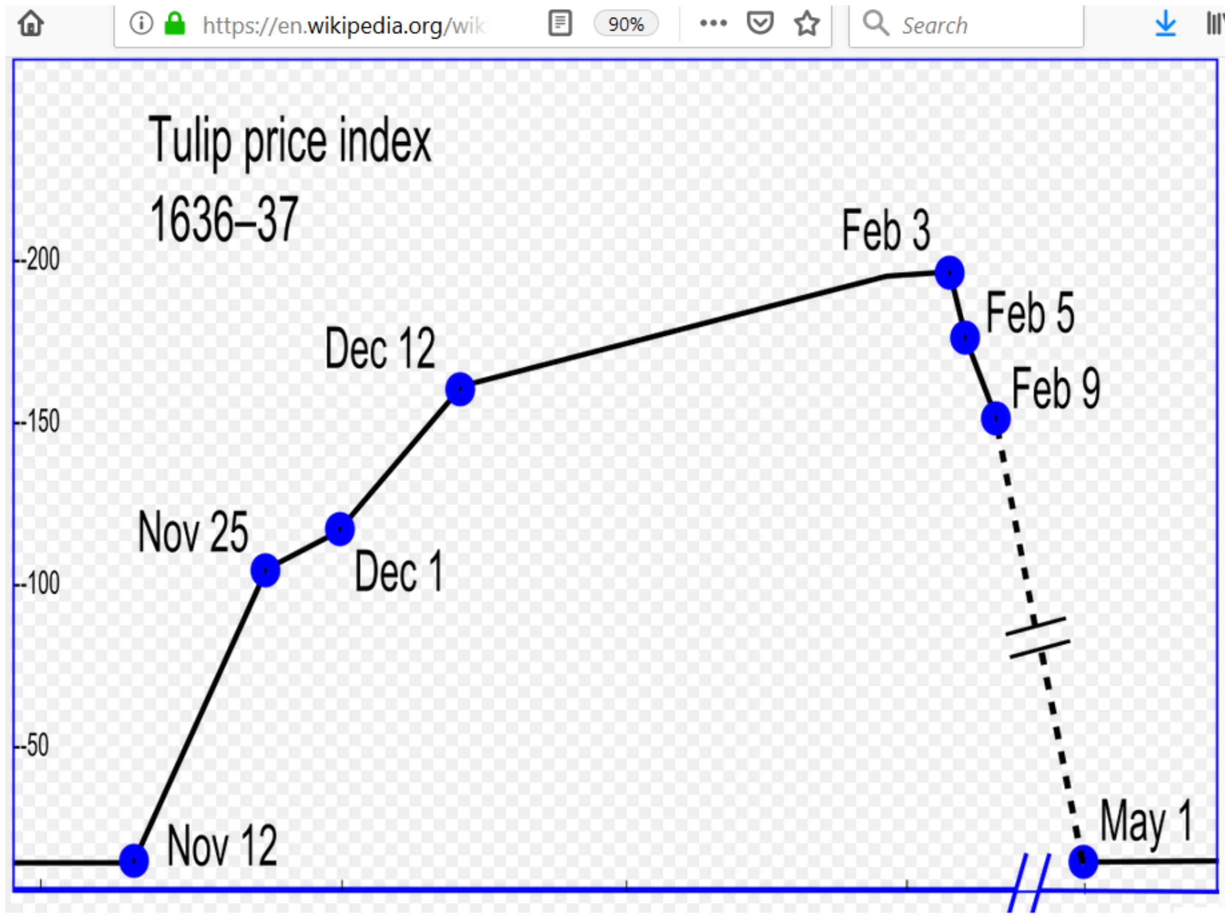
Manias: the frenzied pattersn of purchases, often an increase in prices accompanied by an increase in trading volumes; individuals are eager to buy before the prices increase further.


BEWARE
THE PROFZI SCHEME
DON'T GET SCAMMED!
How Profzi Schemes work:
Faculty convinces young scholars to work in their field.
In order to survive, each scholar must recruit new scholars to follow in their footsteps.
Cites
Advises
Advises
JORGE CHAM © 2009
When funding runs out, the scheme collapses.
WWW.PHDCOMICS.COM

https://en.wikipedia.org/wiki/List_of_commodity_booms#cite_note-

Search

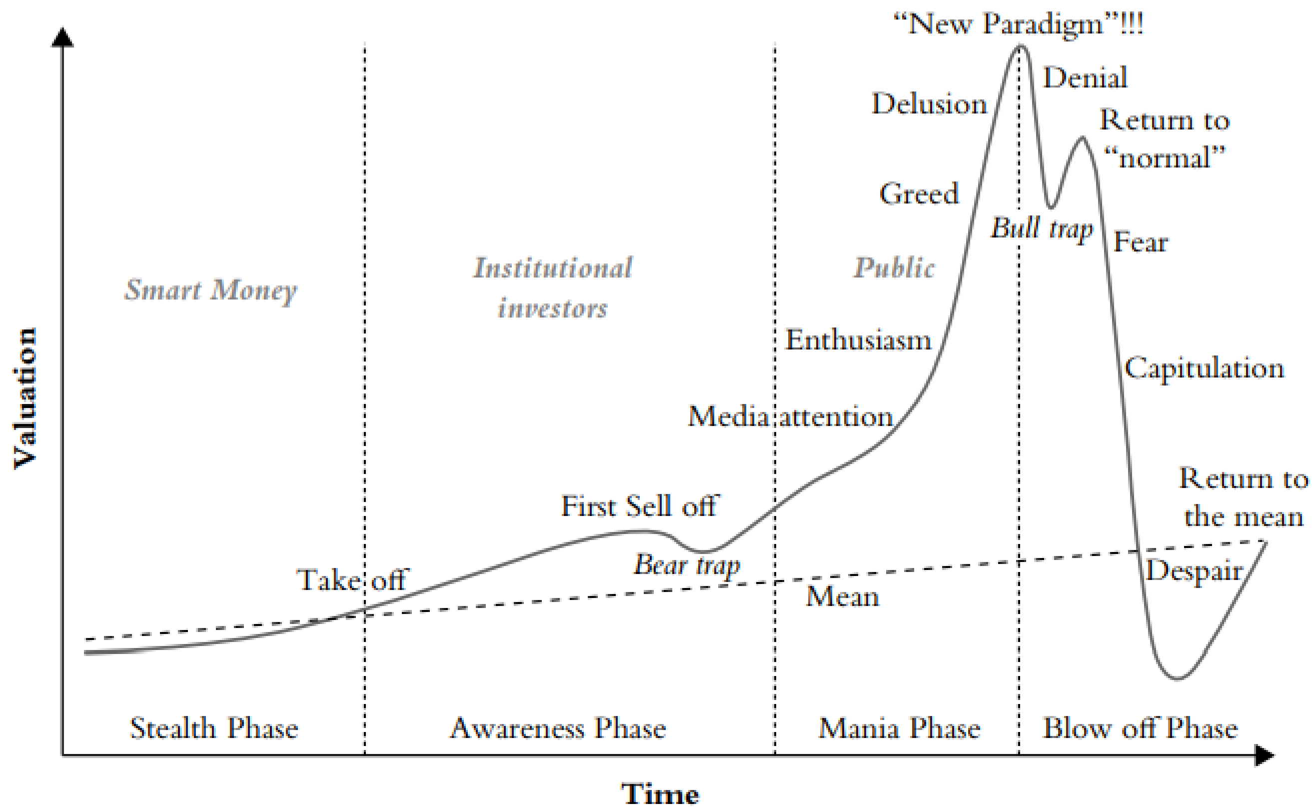
				century
Ohio oil rush	petroleum	fossil fuel	Northwest Ohio, US	1880s – 1930s
Tierra del Fuego gold rush	gold	metal	Tierra del Fuego	1883–1906
Witwatersrand Gold Rush	gold	metal	South Africa	1886
Klondike Gold Rush	gold	metal	Klondike, Yukon, Canada	1896–1899
Mount Baker Gold Rush	gold	metal	Whatcom County, Washington, US	1897 – mid-1920s
Nome Gold Rush	gold	metal	Nome, Alaska, US	1899–1909
Fairbanks Gold Rush	gold	metal	Fairbanks, Alaska, US	early 1900s
Texas oil boom	petroleum	fossil fuel	Texas, US	1901 – 1940s
Cobalt silver rush	silver	metal	Cobalt, Ontario, Canada	1903 – c. 1930
Stoy, Illinois oil boom	petroleum	fossil fuel	Stoy, Illinois, US	1906–1910
Porcupine Gold Rush	gold	metal	Northern Ontario, Canada	1909 – 1950s
Kakamega gold rush	gold	metal	Kakamega, Kenya	early 1930s
Vatukoula gold rush	gold	metal	Vatukoula, Fiji	1932
Second Amazon rubber boom	rubber	agricultural	Amazon basin	1942–1945
Calgary oil boom	petroleum	fossil fuel	Calgary, Alberta, Canada	1947 – early 1980s
New Zealand wool boom	wool	acricultural	New Zealand	1951 – late 1950s
Mexican oil boom	petroleum	fossil fuel	Mexico	1977–1981
2000s commodities boom	multiple	multiple	worldwide	2000s
Uranium bubble of 2007	uranium	metal	worldwide	2005–2007
North Dakota oil boom	petroleum, shale gas	fossil fuel	North Dakota, US	2006 – present (as of 2015)
Rhodium bubble[2]	rhodium	metal	worldwide (primarily South Africa, Russia)	2008



A standardized price index for tulip bulb contracts, created by Earl Thompson. Thompson had no price data between February 9 and May 1, thus the shape of the decline is unknown. The tulip market is known to ha

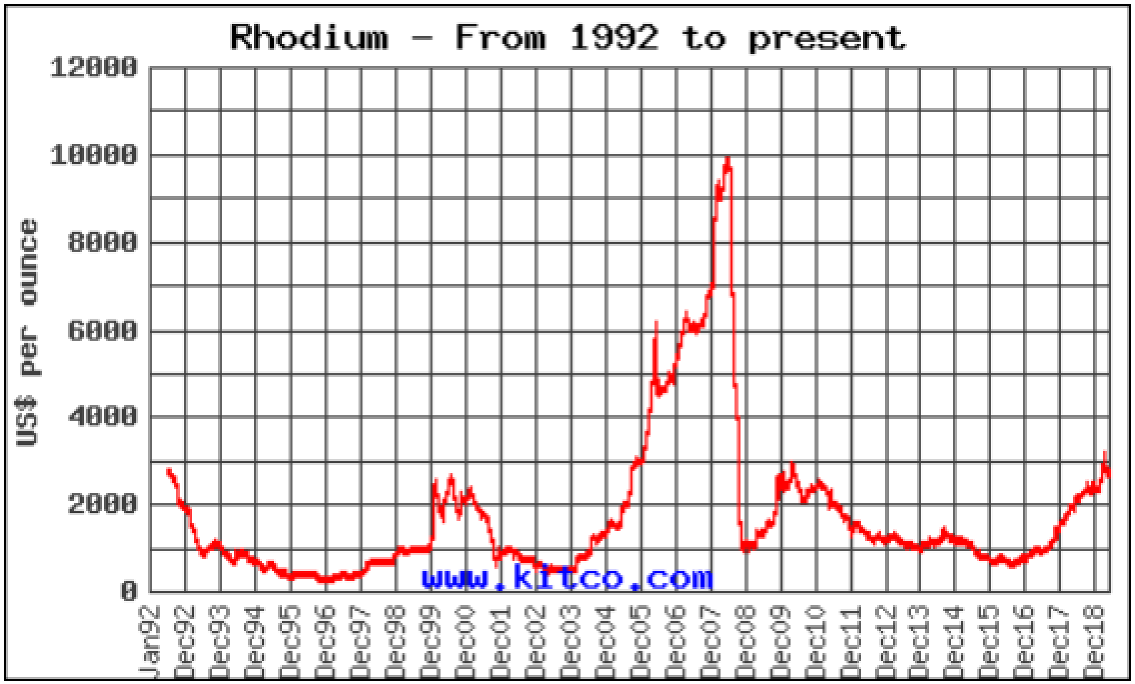
JayHenry - Own work from data of Thompson

(Thompson 2007 Figure 1 pg 101)

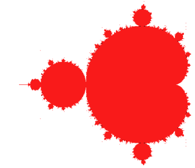


https://www.variantperception.com/2017/09/22/the-anatomy-of-a-bubble/

https://www.kitco.com/charts/historicalrhodium.html



CHAOTIC OSCILLATORS



- example: population dynamics
  - convergence
  - bifurcation
  - chaos
- theory: Verhulst’s logistic equation
- theory: the logistic map
- theory: the Mandelbrot set
- history: logistic equation in oil production
- history: chaos noise in early radio receiver

number of rabbits next year

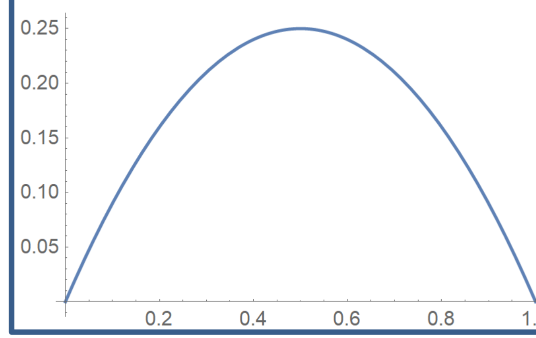
$$x_{n+1} = r\, x_n\, (1 - x_n)$$

growth rate

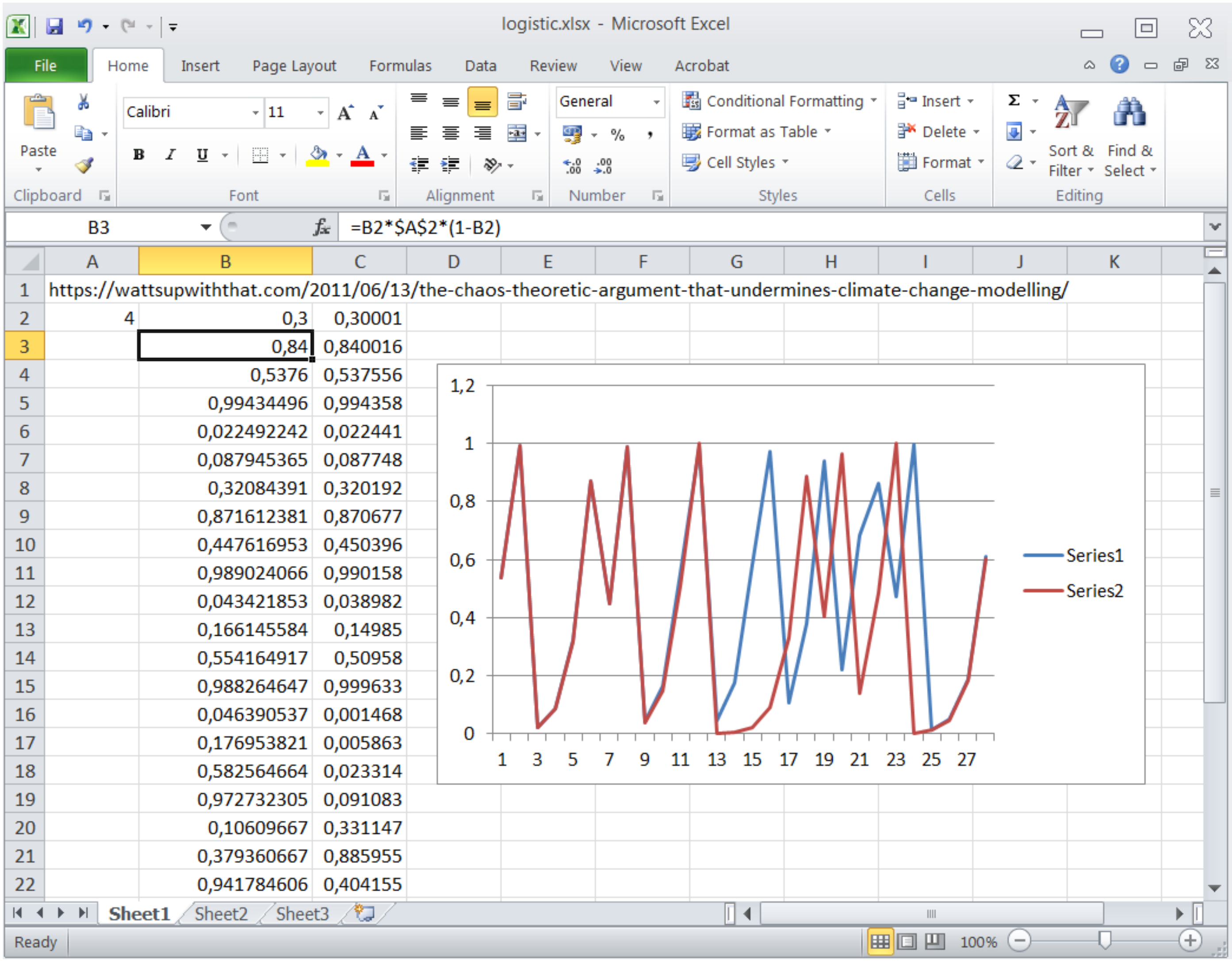
number of rabbits this year

as a fraction of the maximum number of rabits

```
f[x_] := x (1 - x);
Plot[f[x], {x, 0, 1}]
```



Excellent explanation on youtube: “**This equation will change how you see the world** ” (the logistic map) by Veritasium, link https://www.youtube.com/watch?v=ovJcsL7vyrk



Similar: **The Chaos theoretic argument that undermines Climate Change modelling by** [Anthony Watts]() (2011) https://wattsupwiththat.com/2011/06/13/the-chaos-theoretic-argument-that-undermines-climate-change-modelling/

Theory: Verhulst's logistic equation

Indeed, Verhulst published in 1838 a *Note on the law of population growth*. Here are some extracts:

> We know that the famous Malthus showed the principle that the human population tends to grow in a geometric progression so as to double after a certain period of time, for example every twenty five years. This proposition is beyond dispute if abstraction is made of the increasing difficulty to find food [...]
>
> The virtual increase of the population is therefore limited by the size and the fertility of the country. As a result the population gets closer and closer to a steady state.

Verhulst probably realized that Quetelet's mechanical analogy was not reasonable and proposed instead the following (still somewhat arbitrary) differential equation for the population $P(t)$ at time t:

$$\frac{dP}{dt} = rP\left(1 - \frac{P}{K}\right). \tag{6.1}$$

When the population $P(t)$ is small compared to the parameter K, we get the approximate equation

$$\frac{dP}{dt} \simeq rP\,,$$

whose solution is $P(t) \simeq P(0)\,e^{rt}$, i.e. exponential growth[1]. The growth rate decreases as $P(t)$ gets closer to K. It would even become negative if $P(t)$ could exceed K. To get the exact expression of the solution of equation (6.1), we can proceed like Daniel Bernoulli for equation (4.5).

CHAOTIC OSCILLATORS continued

(theory: the logistic map)

Theory: the logistic map

mathworld.wolfram.com/LogisticM 150% Search

Replacing the logistic equation

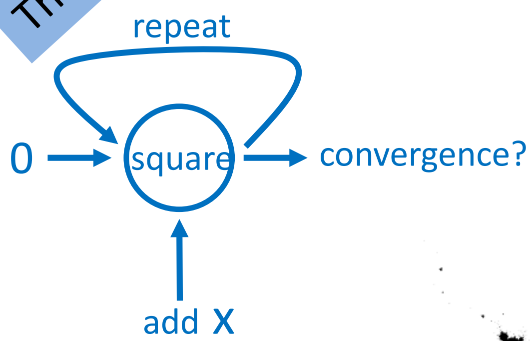
$$\frac{dx}{dt} = r x (1 - x)$$

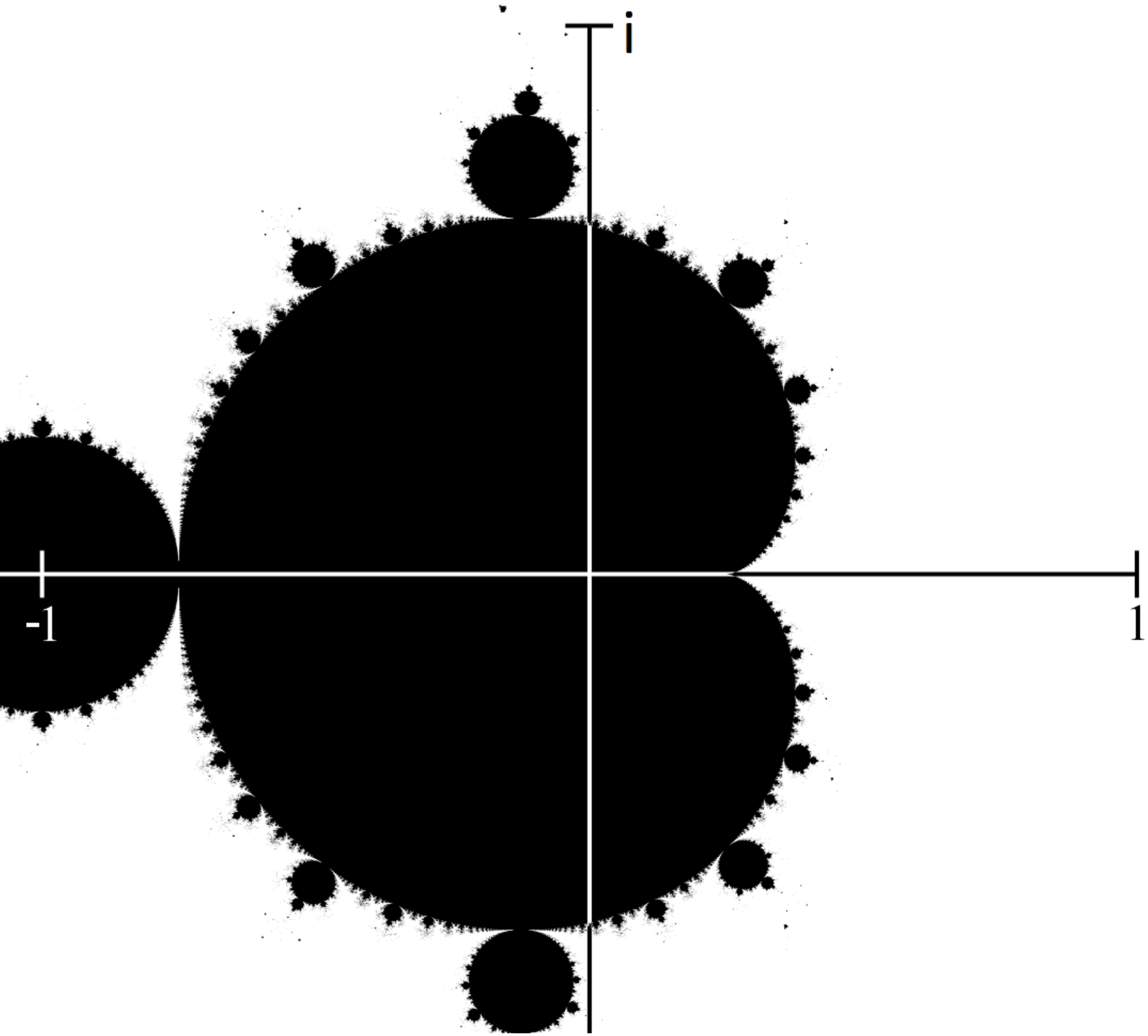
with the quadratic recurrence equation

$$x_{n+1} = r x_n (1 - x_n),$$

where r (sometimes also denoted μ) is a positive constant sometimes known as the "biotic potential" gives the so-called logistic map. This quadratic map is capable of very complicated behavior. While John von Neumann had suggested using the logistic map $x_{n+1} = 4 x_n (1 - x_n)$ as a random number generator in the late 1940s, it was not until work by W. Ricker in 1954 and detailed analytic studies of logistic maps beginning in the 1950s with Paul Stein and Stanislaw Ulam that the complicated properties of this type of map beyond simple oscillatory behavior were widely noted (Wolfram 2002, pp. 918-919).

Theory: the Mandelbrot set





Source: Wikimedia, Mandelbrot set

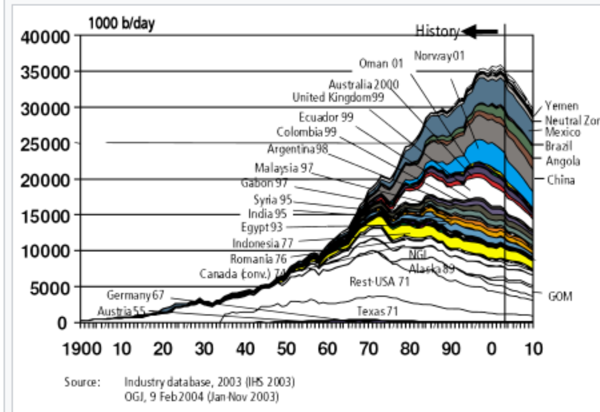
History

ttps://en.wikipedia.org/wiki/Hubbert_peak_theory 120% Search

The **Hubbert peak theory** says that for any given geographical area, from an individual oil-producing region to the planet as a whole, the rate of petroleum production tends to follow a bell-shaped curve. It is one of the primary theories on peak oil.

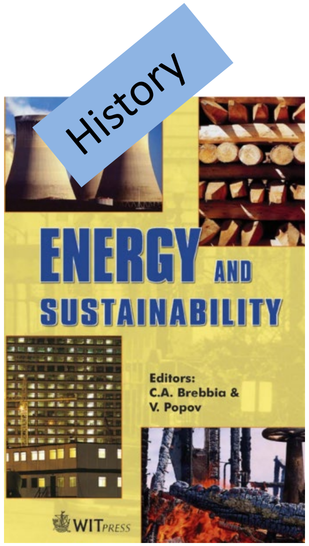
Choosing a particular curve determines a point of maximum production based on discovery rates, production rates and cumulative production. Early in the curve (pre-peak), the production rate increases due to the discovery rate and the addition of infrastructure. Late in the curve (post-peak), production declines because of resource depletion.

The Hubbert peak theory is based on the observation that the amount of oil under the ground in any region is finite, therefore the rate of discovery which initially increases quickly must reach a maximum and decline. In the US, oil extraction followed the discovery curve after a time lag of 32 to 35 years.[1][2]



2004 U.S. government predictions for oil production other than in OPEC and the former Soviet Union

The theory is named after American geophysicist M. King Hubbert, who created a method of modeling the production curve given an assumed ultimate recovery volume.



p.377-384

A physical basis for Hubbert's decline from the midpoint empirical model of oil production

R. J. Wiener[1] & D. M. Abrams[2]
[1]*Research Corporation, USA*
[2]*Department of Earth, Atmospheric, and Planetary Science, MIT, USA*

Hubbert pioneered the idea of using logistic growth to model oil production [1–3]. The logistic growth function satisfies the logistic differential equation $\dot{Q} = r(1 - Q/Q_{tot})Q$, where Q is the quantity that is growing, $\dot{Q}$ is the derivative of Q with respect to time, r is the initial rate of growth, and Q_{tot} is the value to which Q is asymptotically growing. Logistic growth describes any growth process in which the per capita growth rate, $\dot{Q}/Q$, decreases linearly as Q increases. In the case of oil production, Q represents the cumulative oil produced (*e.g.* in barrels), $\dot{Q}$ represents the production rate (*e.g.* in barrels per day), and Q_{tot} represents the total recoverable oil that ultimately will be produced from a reservoir or, more broadly, from an oil producing region. $Q = Q_{tot}/(1+\exp(r(t_m - t)))$ is the solution to logistic differential equation, where t_m is the midpoint time (*i.e.* the time at which Q has grown to $Q_{tot}/2$). The

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History

Chaotic Behavior in Super Regenerative Detectors

Domine M. W. Leenaerts, *Member, IEEE*

***Abstract*— In this paper the super regenerative detector, as proposed by Armstrong in 1922, will be investigated. We will show that in a simplified model the current in the circuit behaves chaotically during a small period in time after which the circuit becomes an oscillator. Armstrong was not aware of the circuits' chaotic behavior, but reported strange irregular start-ups of the oscillator. Chaotic behavior of the circuit will be demonstrated in this paper using computer simulation. During the period in which the irregularities appear, the amplification of the circuit is maximal.**

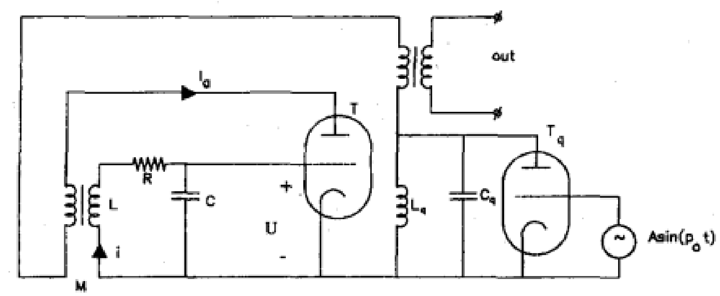


Fig. 1. The super regenerative detector. In his paper Armstrong did use Western Electric Type L tubes but did not give information on the other components. The sources biasing the tubes are left out for convenience.

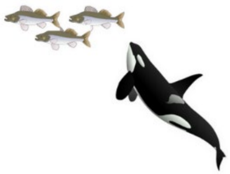
I. Introduction

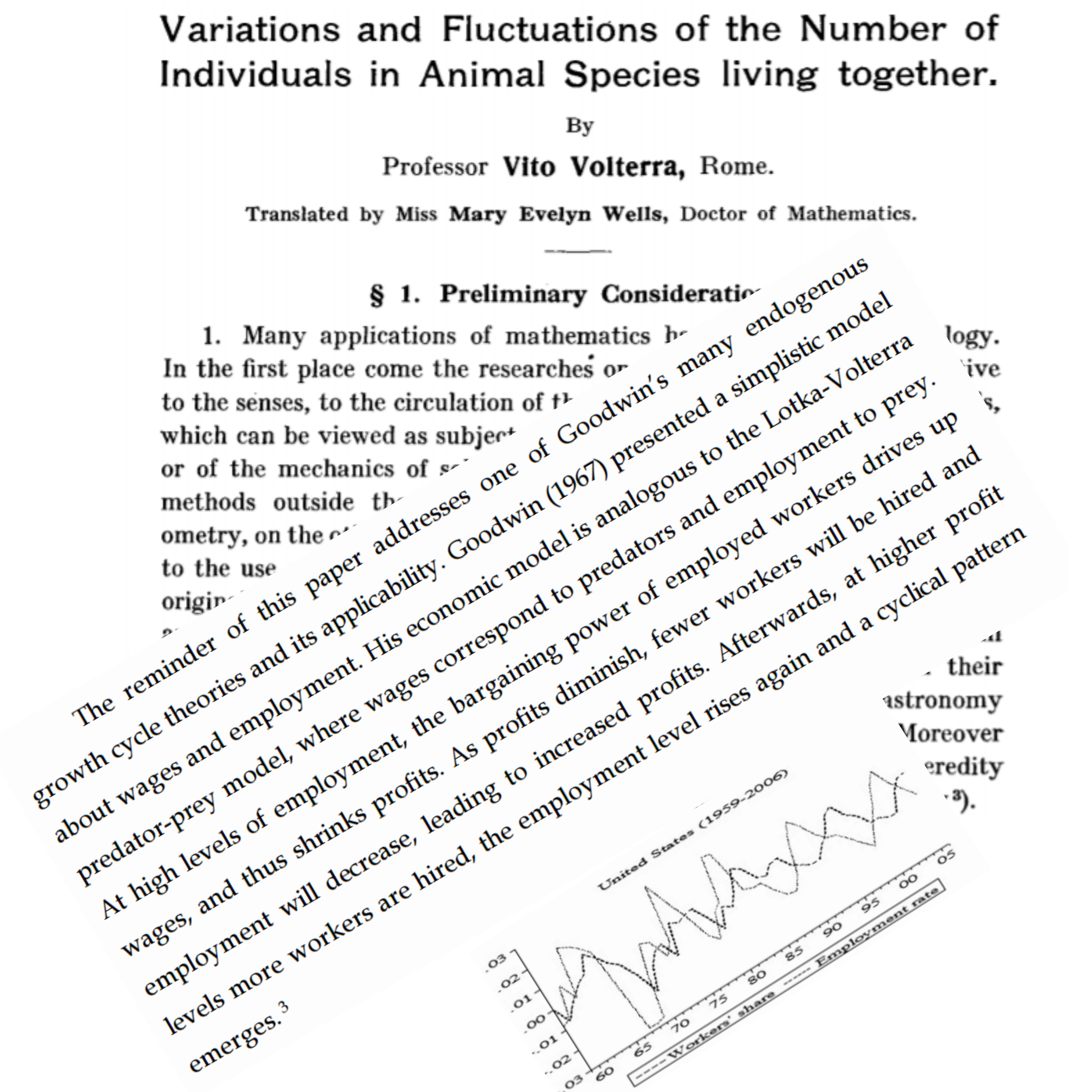
In 1922, Armstrong invented the (super)regenerative circuit as a detector with higher sensitivity and selectivity as compared to other types of receivers [1]. This type of detection was often used in radio engineering in the early days following this invention. Nowadays, regenerative detectors are still used as predetection systems when very high frequencies (e.g., microwave communication) are involved [2]. The regenerative detector is favorably used in applications where simplicity and compactness outweigh the need for low noise reception. Because a single tube may be used in the receiver as well as in the transmitter, this kind of circuits is typically found in radar beacon applications.

In a super regenerative detector the inductive coupling between the plate and grid circuits of the detector tube via coil L is such that self-sustained oscillations can be built applied to the plate of the tube (see Fig. 1) and inductively fed back to the oscillators' grid circuit.

Although the basic operation of the circuit was understood, there still was the problem of the characteristic noise generated in those circuits. One assumed that the characteristic noise, which could be heard in the earphones, was caused by the noise from the circuits components (e.g., tubes) and amplified during the start-up of the oscillation. In this paper we will show that the behavior of a simplified model of the detector is chaotic. This behavior exhibits during the start-up of the free oscillations under certain conditions. Before operating as an oscillator, there is a period in which the behavior of the current is irregular. It turns out that the detector also has the maximal amplification factor when it operates chaotically.

PREDATOR PREY SYSTEMS





Variations and Fluctuations of the Number of Individuals in Animal Species living together.

By

Professor **Vito Volterra**, Rome.

Translated by Miss **Mary Evelyn Wells**, Doctor of Mathematics.

§ 1. Preliminary Consideratio

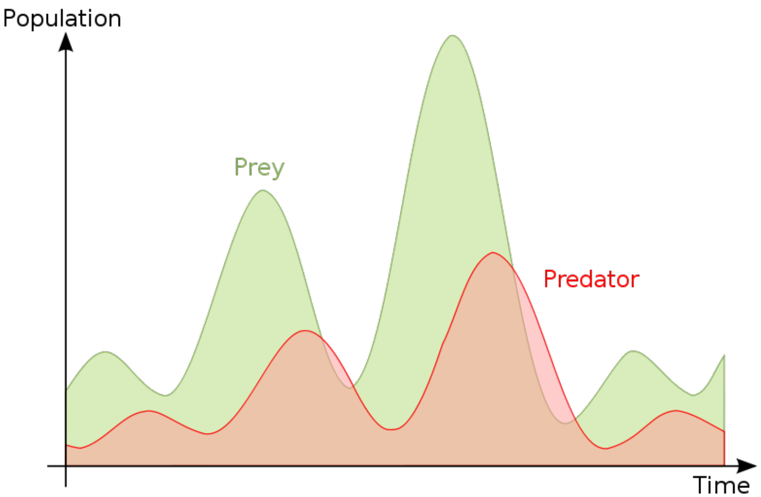
1. Many applications of mathematics h… …logy. In the first place come the researches or… …ive to the senses, to the circulation of t… …s, which can be viewed as subjec… or of the mechanics of s… methods outside th… ometry, on the c… to the use… origin… …their …astronomy …Moreover …eredity …3).

The reminder of this paper addresses one of Goodwin's many endogenous growth cycle theories and its applicability. Goodwin (1967) presented a simplistic model about wages and employment. His economic model is analogous to the Lotka-Volterra predator-prey model, where wages correspond to predators and employment to prey. At high levels of employment, the bargaining power of employed workers drives up wages, and thus shrinks profits. As profits diminish, fewer workers will be hired and employment will decrease, leading to increased profits. Afterwards, at higher profit levels more workers are hired, the employment level rises again and a cyclical pattern emerges.[3]

$$\frac{dx}{dt} = Ax - Bxy$$

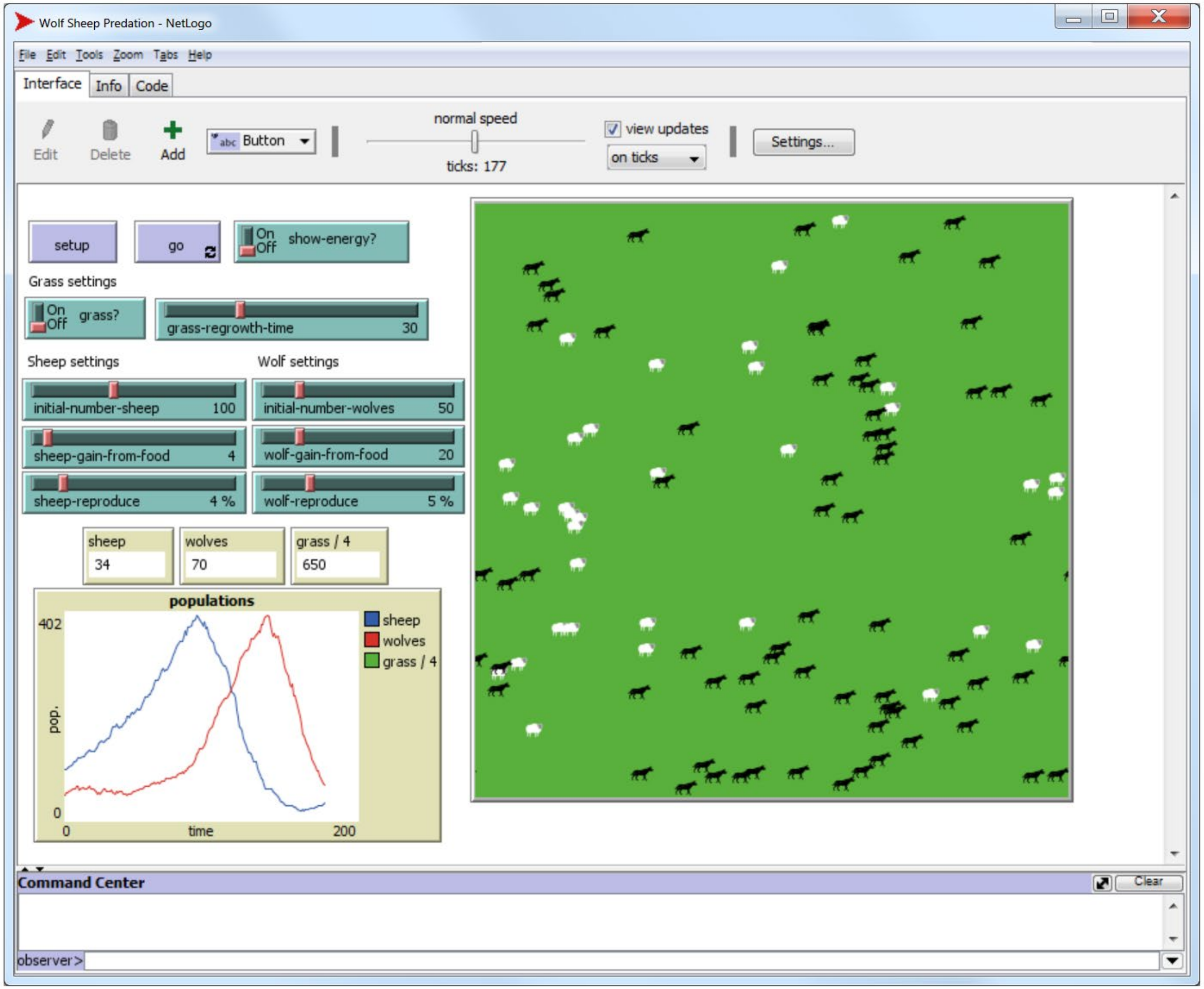
$$\frac{dy}{dt} = -Cy + Dxy$$

Lotke Volterra equations, x being the size of the prey population, y the predators, t is time and A,B,C,D, are parameters



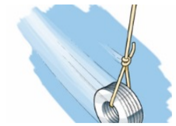
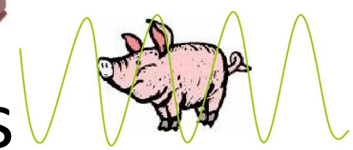
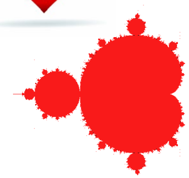
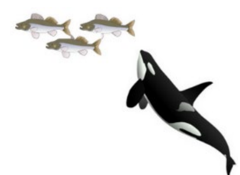
Source:Volterra, V. (1928). Variations and fluctuations of the nu… of individuals in animal species living together. *J. Cons. Int. Explor. Mer*, *3*(1), 3-51.
(across: V Vadasz - 2007).. http://www.scielo.org.co

Demo


Wolf Sheep Predation - NetLogo
File Edit Tools Zoom Tabs Help
Interface
Info
Code
Edit
Delete
Add
Button
normal speed
ticks: 177
view updates
on ticks
Settings...
setup
go
On
Off
show-energy?
Grass settings
On
Off
grass?
grass-regrowth-time 30
Sheep settings
Wolf settings
initial-number-sheep 100
initial-number-wolves 50
sheep-gain-from-food 4
wolf-gain-from-food 20
sheep-reproduce 4 %
wolf-reproduce 5 %
sheep
34
wolves
70
grass / 4
650
populations
402
pop.
0
0
time
200
sheep
wolves
grass / 4
Command Center
Clear
observer>

Recap: where are we?

TYPES OF OSCILLATIONS

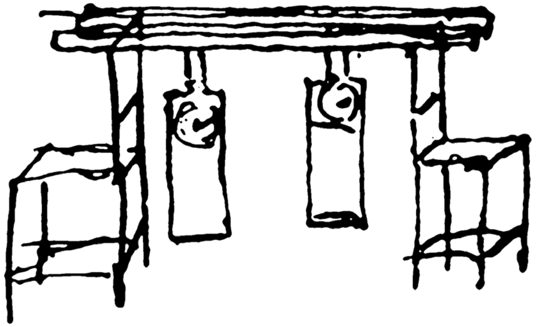
- free systems 
- tuned oscillators 
- phase shift oscillators 
- relaxation oscillators 
- chaotic oscillators 
- predator-prey systems 

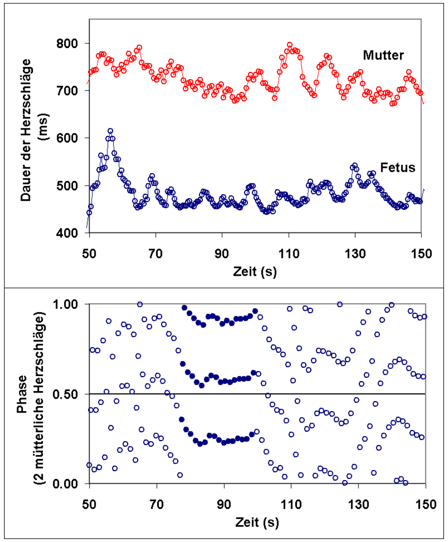
oscillations act upon each other

- synchronisation
- modulation
- forcing

Sources: www.scientificamerican.com/, www.ldoceonline.com, www.slideshare.net/Carolederks/samenvatting-belevenis-economie-presentation, rheingoldheavy.com/arduino-from-scratch-part-9-16mhz-crystal-oscillator, www.biologycorner.com/worksheets/predatorsim.html

SYNCHRONISATION

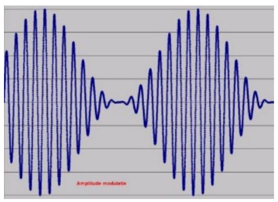




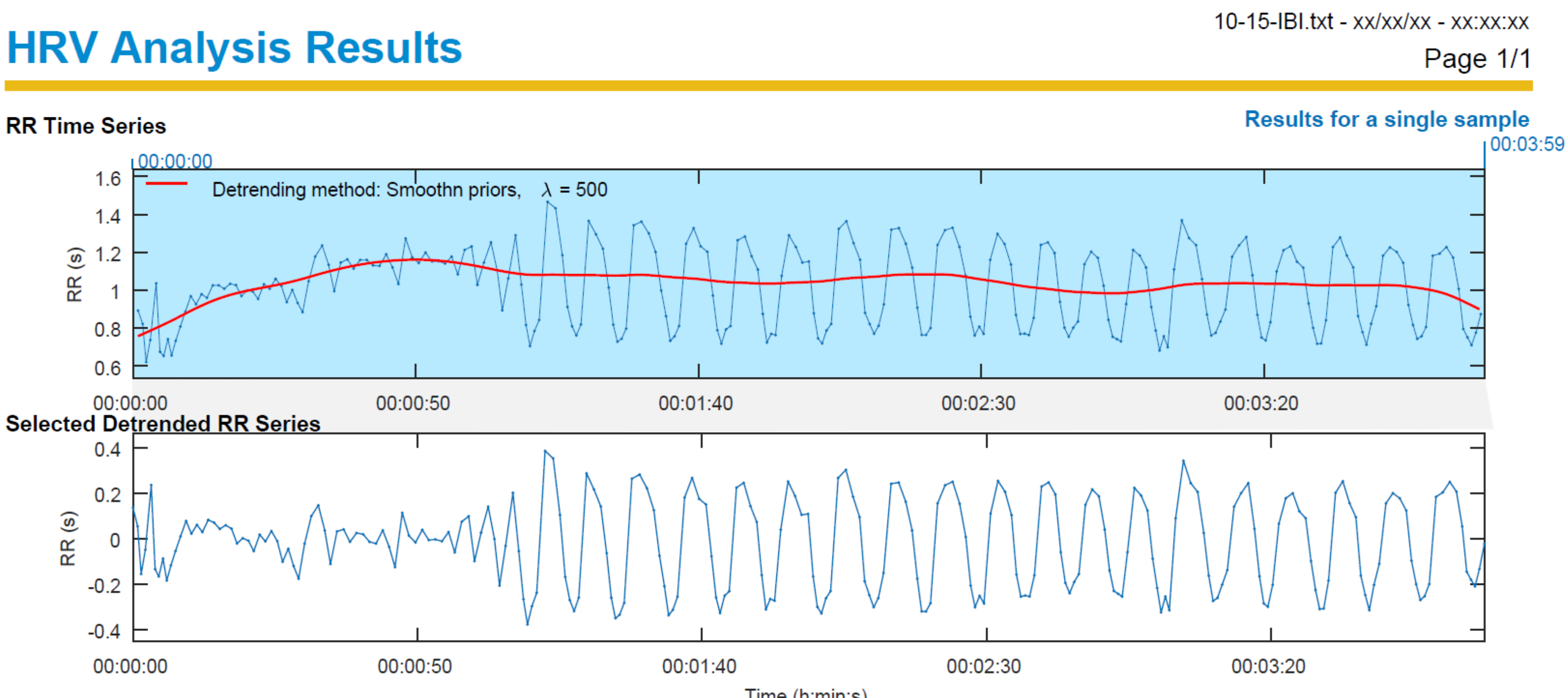
Source: http://www.michaelfalkner.de/herzmusik/gleichtakt.html
http://www.scholarpedia.org/article/Synchronization

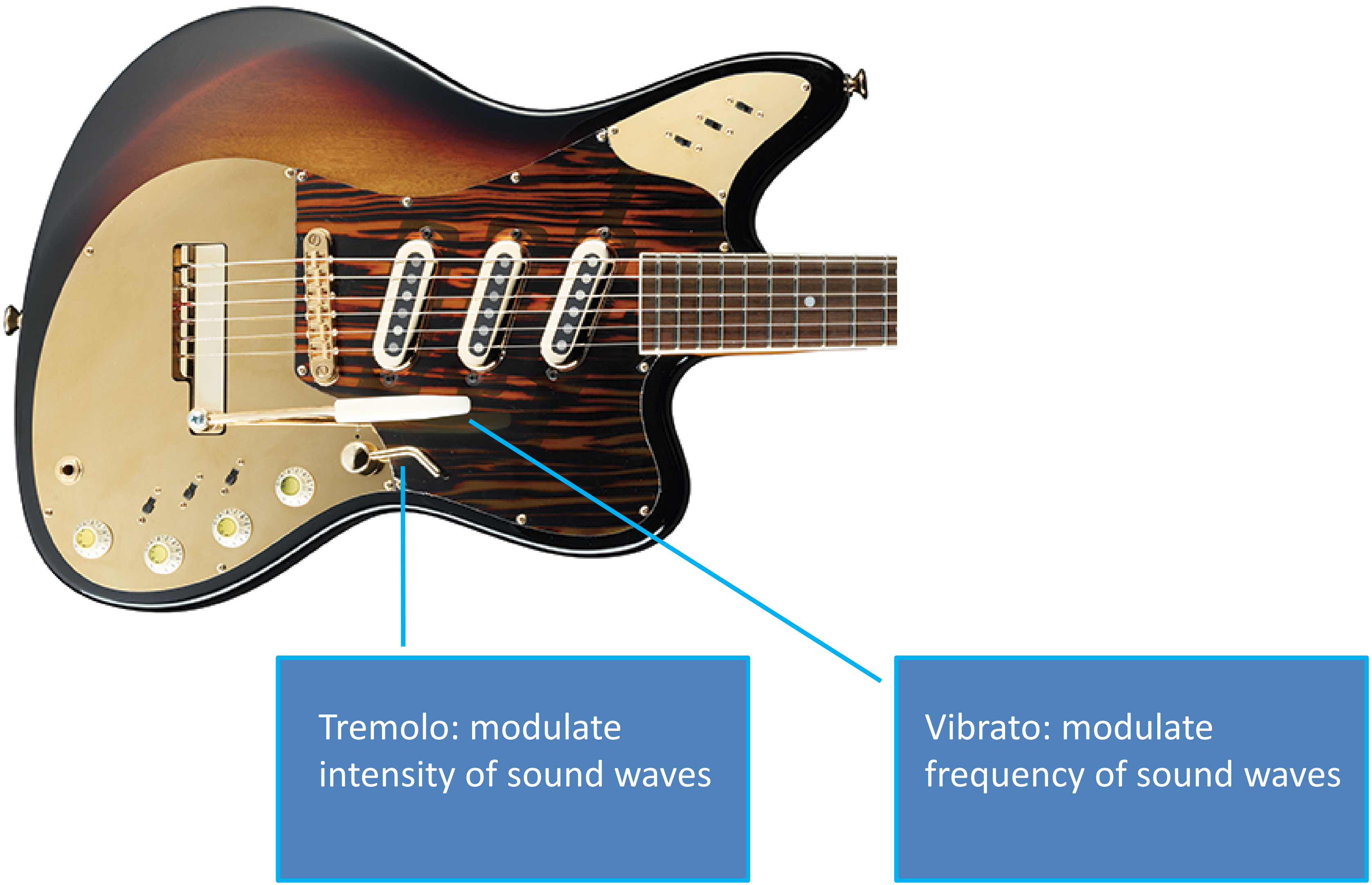
MODULATION

- amplitude modulation



- frequency modulation



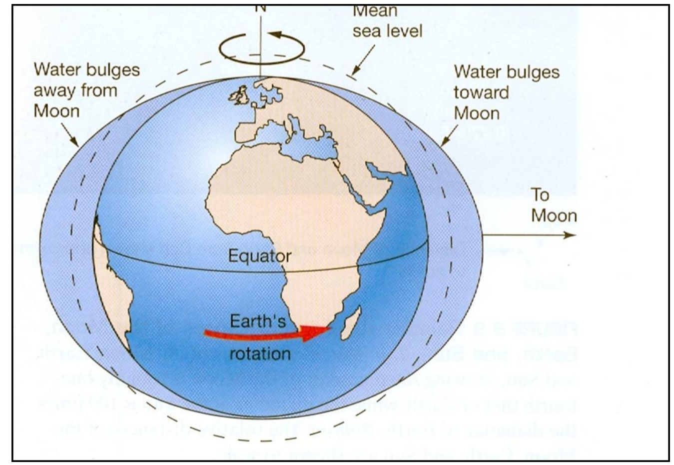

Tremolo: modulate intensity of sound waves
Vibrato: modulate frequency of sound waves

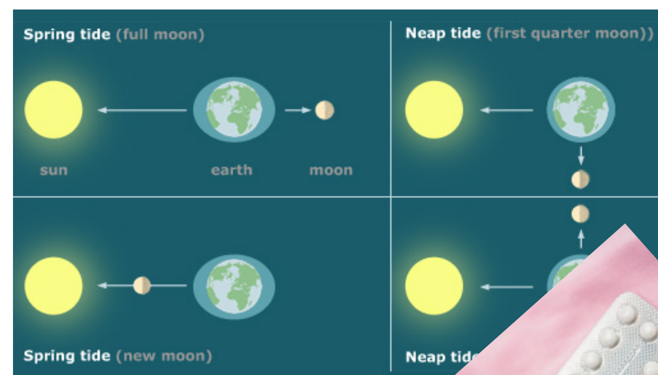
FORCING

Katwijk.info

juni 2017

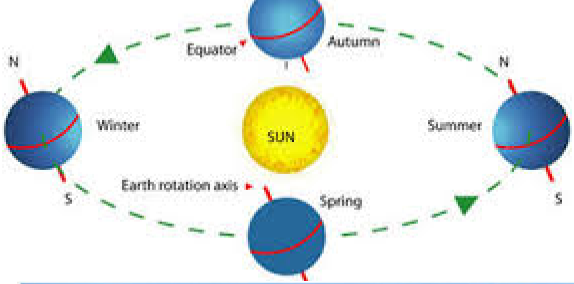
vrijdag 9 juni	4:00 uur	105 cm
	11:40 uur	-63 cm
	16:20 uur	107 cm
zaterdag 10 juni	0:26 uur	-79 cm
	4:32 uur	111 cm
	12:10 uur	-63 cm
	16:48 uur	106 cm
zondag 11 juni	0:55 uur	-84 cm
	5:06 uur	114 cm
	12:47 uur	-65 cm
	17:25 uur	103 cm
maandag 12 juni	1:31 uur	-89 cm
	5:39 uur	115 cm
	13:30 uur	-67 cm
	17:59 uur	98 cm
dinsdag 13 juni	2:06 uur	-92 cm
	6:16 uur	112 cm





Applying an external periodic force to a system (which may have internal feedback or resonance)

Source: katwijk.info/nl/getijc ed.php#Info, en.es-static.us/upl/2012/10/tw dal_bulges_earth.jpeg, www.ecomare.nl/fileadmin/ecomare/data/images/springti



Chanel Lente/Zomer 2019

Chanel Herfst/Winter 2019

S/S

FASHION SYSTEM

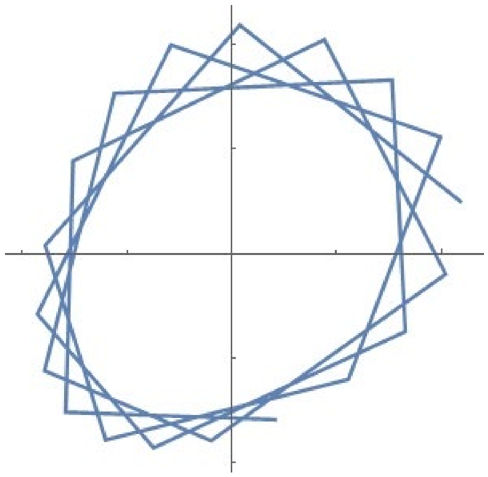
	JAN	FEB	MARC H	APRI L	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
RESEARCH												
DESIGN												
FABRIC SOURCING												
FIRST PATTERNS												
FABRIC SELECTION												
FABRIC ORDER												
FITTINGS												
FABRIC ARRIVES												
FINAL PROTOTYPES												
SEND FOR SAMPLING												
SAMPLES ARRIVE												
FINAL FITTING (SHOW)												
SHOW												

F/W

CRITICAL PATH
FASHION SYSTEM

	JAN	FEB	MARC H	APRI L	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
RESEARCH												
DESIGN												
FABRIC SOURCING												
FIRST PATTERNS												
FABRIC SELECTION												
FABRIC ORDER												
FITTINGS												
FABRIC ARRIVES												
FINAL PROTOTYPES												
SEND FOR SAMPLING												
SAMPLES ARRIVE												
FINAL FITTING (SHOW)												
SHOW												

Source: https://subconsciousseamstress.wordpress.com/2013/10/31/critical-path/



Thank you for your attention

Loe Feijs

l.m.g.feijs@tue.nl