# “Toybox” Tools to Soften the Mathematical Blow

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# Agenda

- What is the problem?
- Why Excel?
- Some examples
  - Engineering
  - Other
- Underlying techniques for the geeks
- Student reaction

# What is the problem?

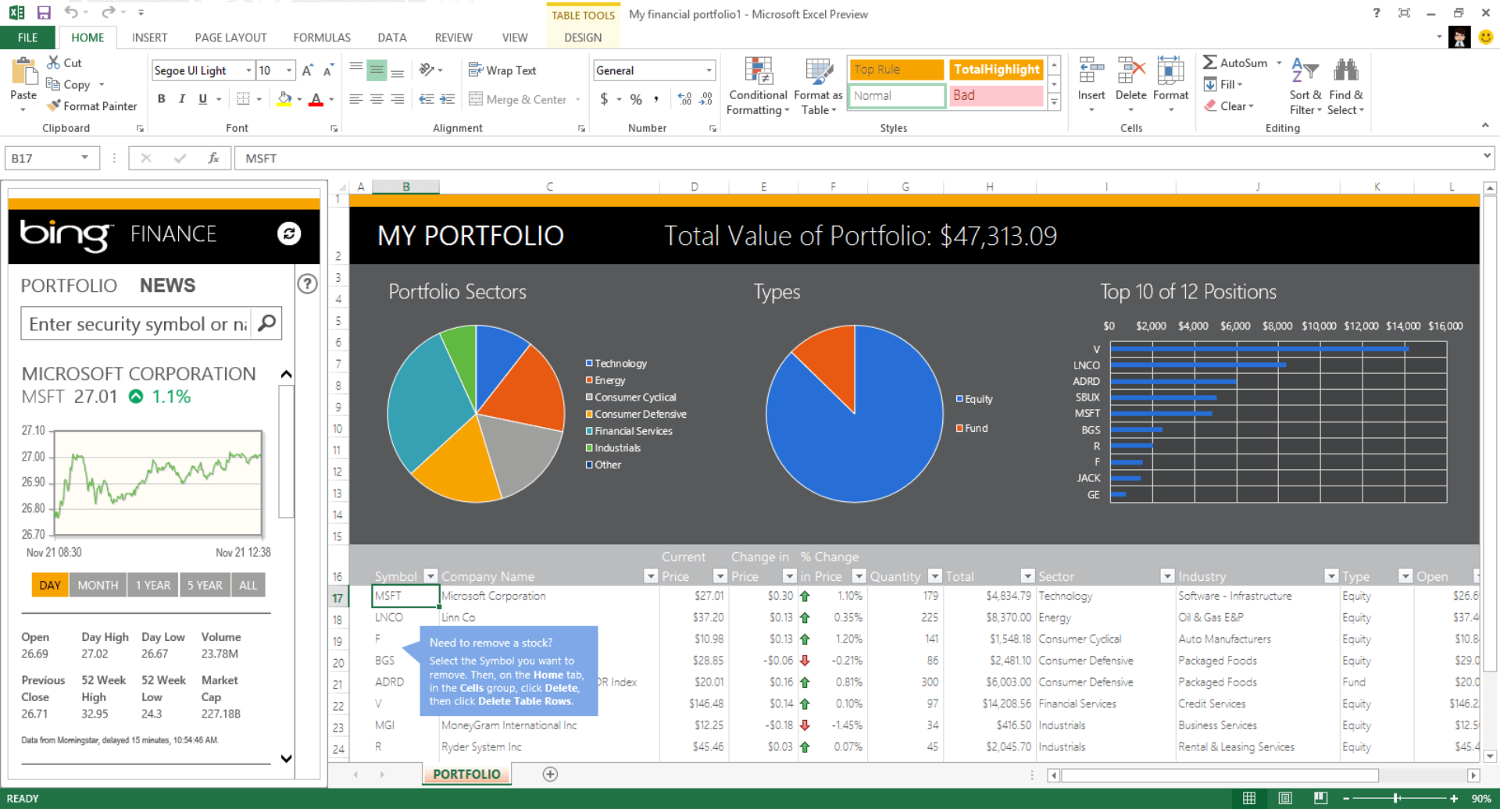
elbow – the best band in the land!

Electronic form of a physical reality.


Mathematical expression of a physical reality.

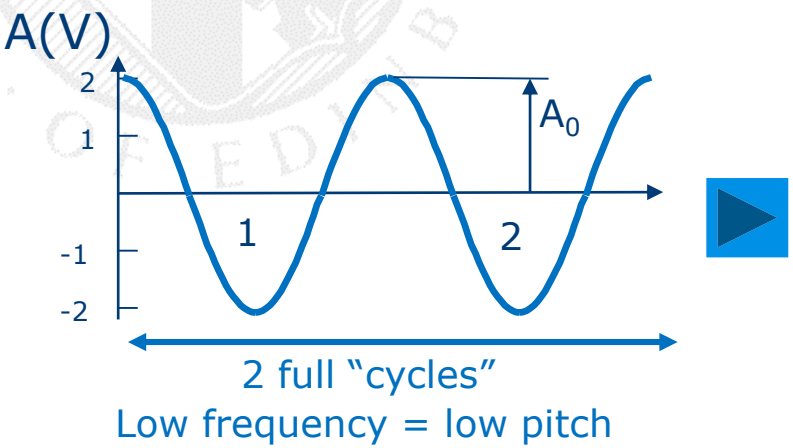
$$V = \sum_{n=0}^{n=\infty} V_n \cos\left(n\omega_0 + \phi_n\right)$$

# Why Excel?

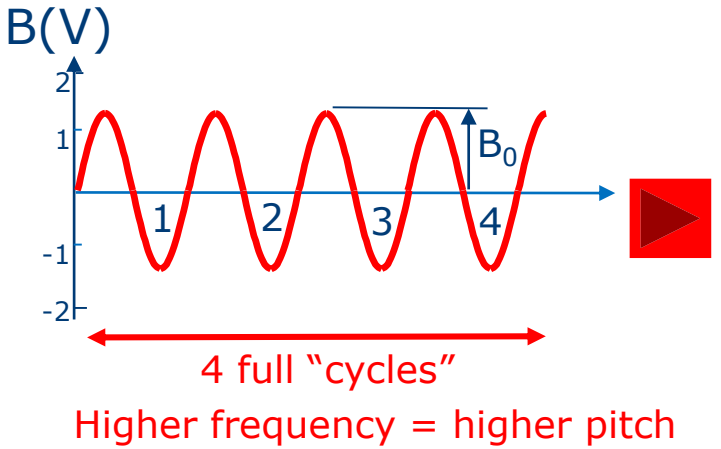

My financial portfolio1 - Microsoft Excel Preview
MY PORTFOLIO
Total Value of Portfolio: $47,313.09
Portfolio Sectors
Technology
Energy
Consumer Cyclical
Consumer Defensive
Financial Services
Industrials
Other
Types
Equity
Fund
Top 10 of 12 Positions
$0 $2,000 $4,000 $6,000 $8,000 $10,000 $12,000 $14,000 $16,000
V
LNCO
ADRD
SBUX
MSFT
BGS
R
F
JACK
GE
bing FINANCE
PORTFOLIO NEWS
Enter security symbol or n
MICROSOFT CORPORATION
MSFT 27.01 1.1%
27.10
27.00
26.90
26.80
26.70
Nov 21 08:30
Nov 21 12:38
DAY MONTH 1 YEAR 5 YEAR ALL
Open 26.69
Day High 27.02
Day Low 26.67
Volume 23.78M
Previous Close 26.71
52 Week High 32.95
52 Week Low 24.3
Market Cap 227.18B
Data from Morningstar, delayed 15 minutes, 10:54:46 AM.
Symbol
Company Name
Current Price
Change in Price
% Change in Price
Quantity
Total
Sector
Industry
Type
Open
MSFT Microsoft Corporation $27.01 $0.30 1.10% 179 $4,834.79 Technology Software - Infrastructure Equity $26.6
LNCO Linn Co $37.20 $0.13 0.35% 225 $8,370.00 Energy Oil & Gas E&P Equity $37.4
F $10.98 $0.13 1.20% 141 $1,548.18 Consumer Cyclical Auto Manufacturers Equity $10.8
BGS $28.85 -$0.06 -0.21% 86 $2,481.10 Consumer Defensive Packaged Foods Equity $29.0
ADRD $20.01 $0.16 0.81% 300 $6,003.00 Consumer Defensive Packaged Foods Fund $20.0
V $146.48 $0.14 0.10% 97 $14,208.56 Financial Services Credit Services Equity $146.2
MGI MoneyGram International Inc $12.25 -$0.18 -1.45% 34 $416.50 Industrials Business Services Equity $12.5
R Ryder System Inc $45.46 $0.03 0.07% 45 $2,045.70 Industrials Rental & Leasing Services Equity $45.4
Need to remove a stock?
Select the Symbol you want to remove. Then, on the Home tab, in the Cells group, click Delete, then click Delete Table Rows.
PORTFOLIO
READY
90%

# Example#1 - Electrical Signals (e.g. Sound)

$$A = A_0 \cos(\omega_A t), \quad \omega_A = 2\pi f_A$$



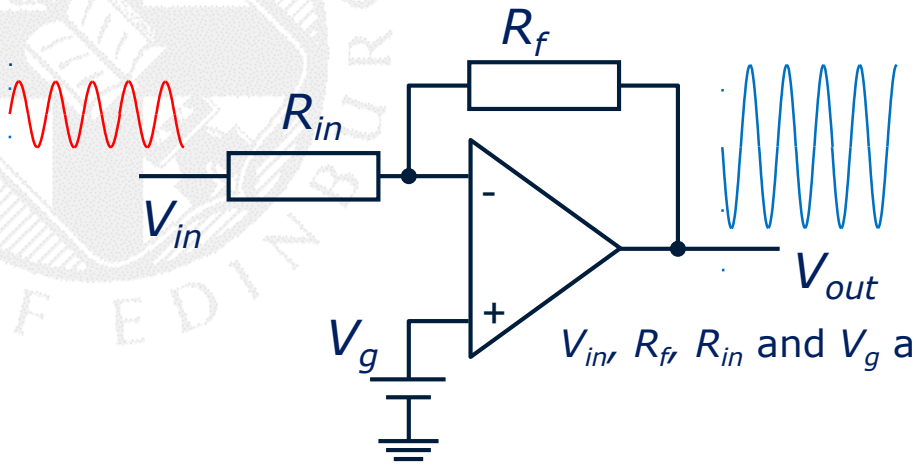

$$B = B_0 \cos(\omega_B t + \phi_B), \quad \omega_B = 2\pi f_B$$




- Students tend to understand $A_0$ and $B_0$ – the height of the signals
  - *Volume in a sound signal – A is louder than B*
- But are unsure about frequency, f
  - *Pitch in a sound signal*
- And are very unsure about phase, $\emptyset_B$

Toybox tool – amplitude, frequency, phase

# Example#2 – A Simple Circuit




$V_{in}$, $R_f$, $R_{in}$ and $V_g$ are all adjustable

$$V_{out} = -\left(\frac{R_f}{R_{in}}\right) \times V_{in} + \left(\frac{R_f + R_{in}}{R_{in}}\right) \times V_g$$

Toybox tool – inverting circuit

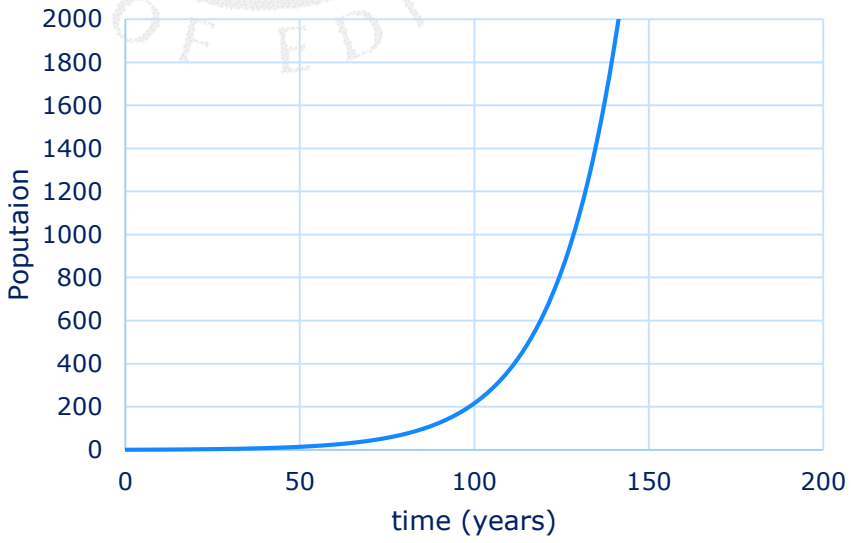
# Example#3 – Population Growth

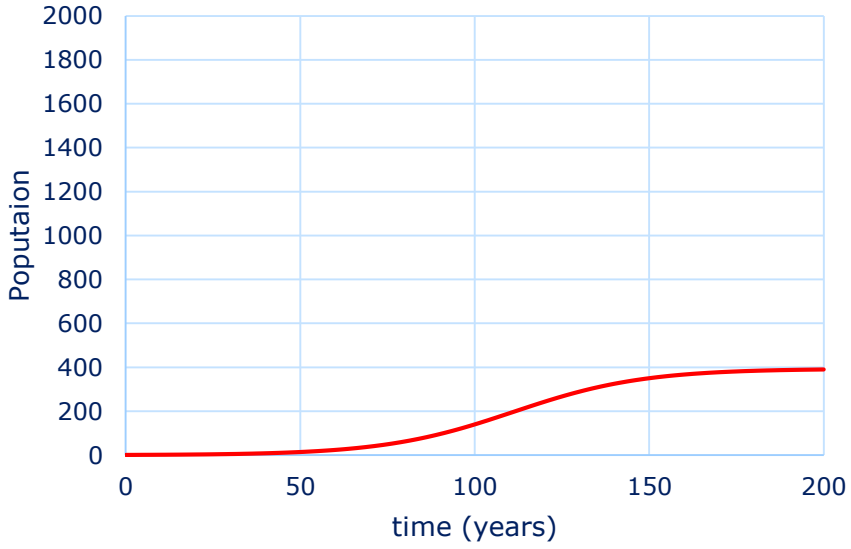
Exponential Growth, $N_t = N_0 e^{rt}$

$N_0$ = initial population
$r$ = rate of growth

Logistic Growth, $N_t = \dfrac{K}{1 + \left(\dfrac{K - N_0}{N_0}\right) e^{-rt}}$

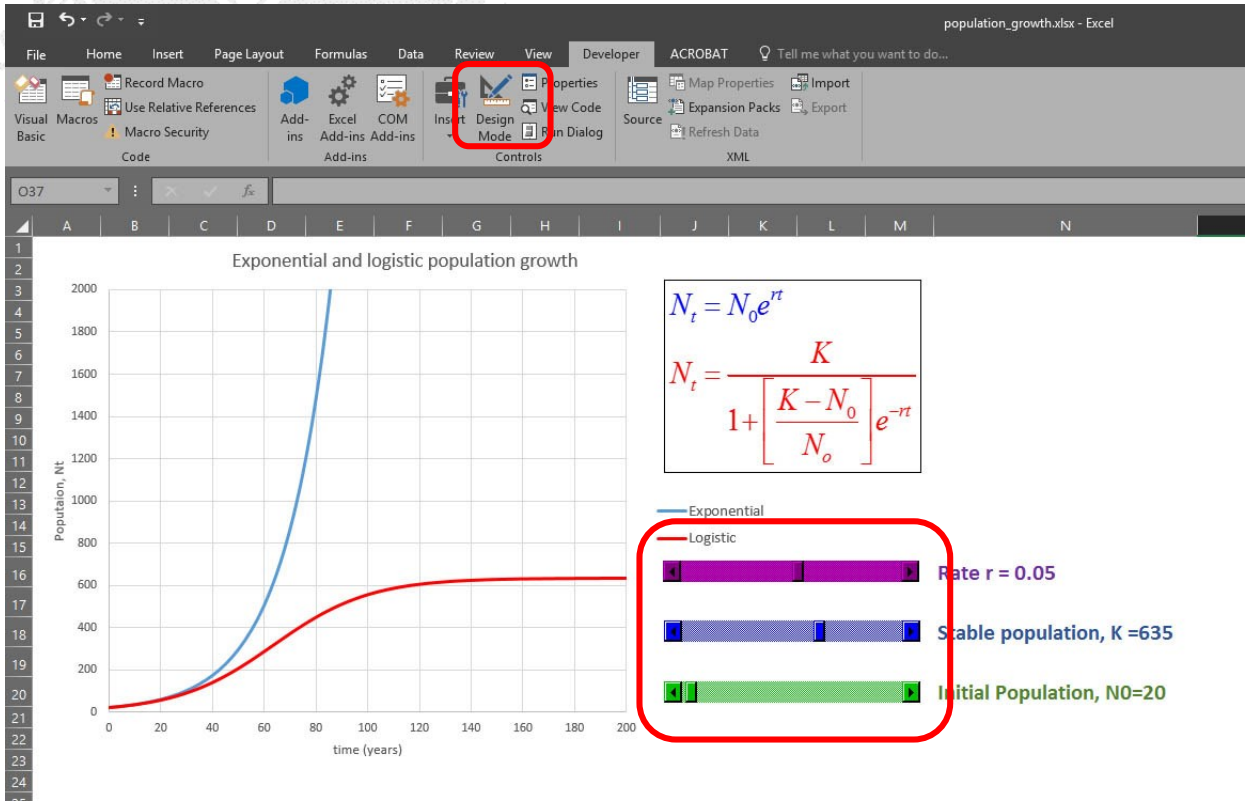
$K$ = sustainable population

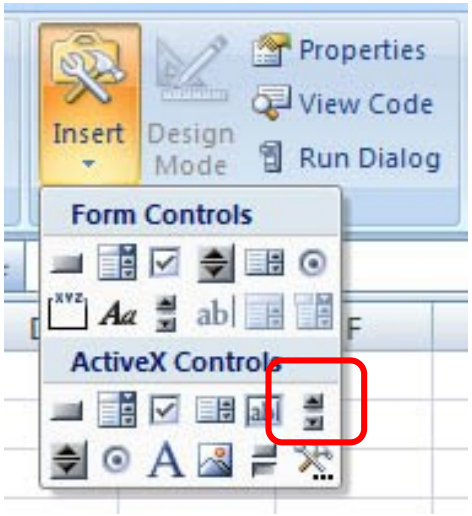



Toybox tool - population growth

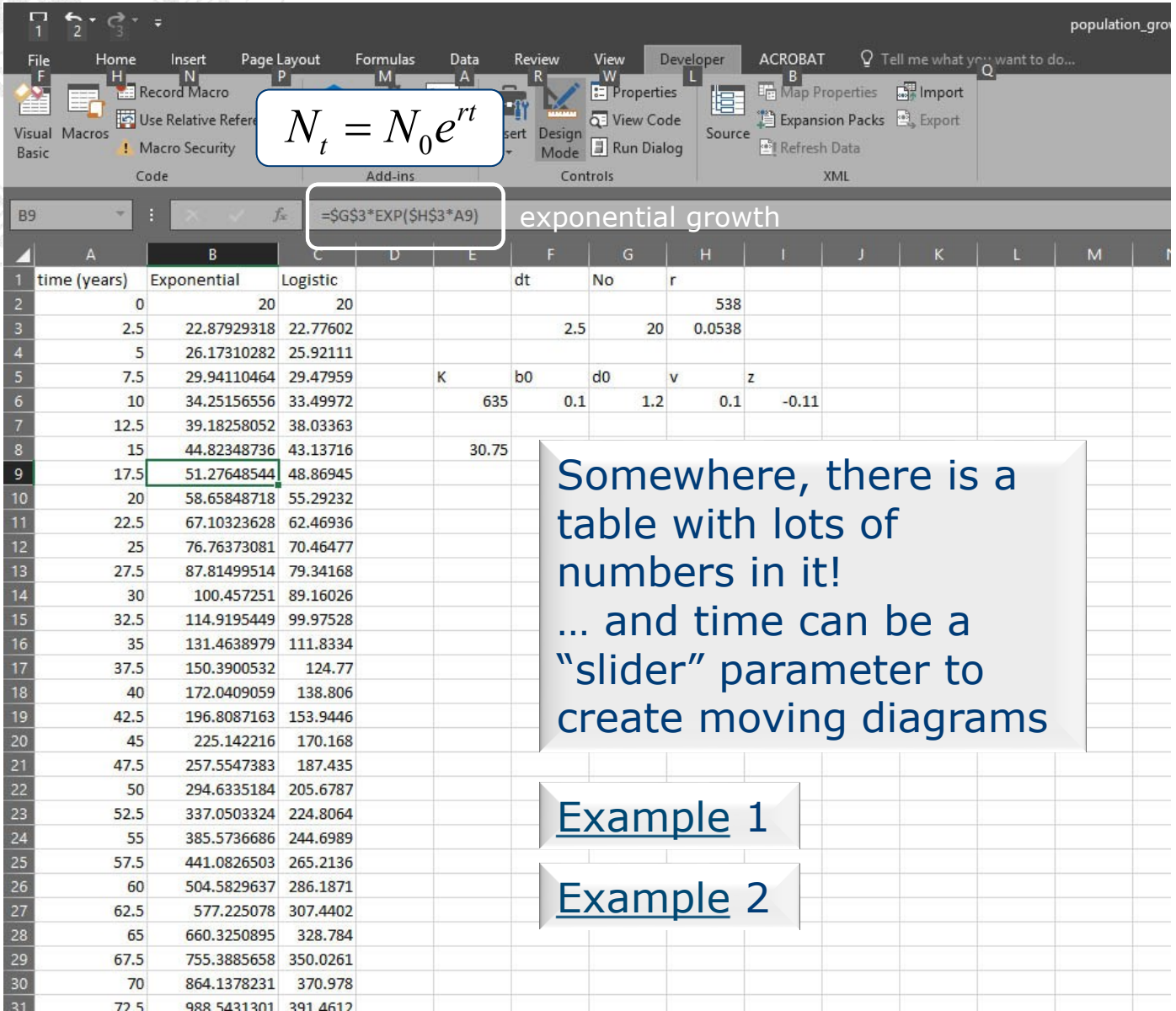
# How to do this?




Use "slider" controls and others …
e.g. tick boxes
Insert equations and diagrams as appropriate
… and hide the grid!

# How to do this?




| | A | B | C | D | E | F | G | H | I | J | K | L | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | time (years) | Exponential | Logistic | | | dt | No | r | | | | | |
| 2 | 0 | 20 | 20 | | | | | 538 | | | | | |
| 3 | 2.5 | 22.87929318 | 22.77602 | | | 2.5 | 20 | 0.0538 | | | | | |
| 4 | 5 | 26.17310282 | 25.92111 | | | | | | | | | | |
| 5 | 7.5 | 29.94110464 | 29.47959 | | K | b0 | d0 | v | z | | | | |
| 6 | 10 | 34.25156556 | 33.49972 | | 635 | 0.1 | 1.2 | 0.1 | -0.11 | | | | |
| 7 | 12.5 | 39.18258052 | 38.03363 | | | | | | | | | | |
| 8 | 15 | 44.82348736 | 43.13716 | | 30.75 | | | | | | | | |
| 9 | 17.5 | 51.27648544 | 48.86945 | | | | | | | | | | |
| 10 | 20 | 58.65848718 | 55.29232 | | | | | | | | | | |
| 11 | 22.5 | 67.10323628 | 62.46936 | | | | | | | | | | |
| 12 | 25 | 76.76373081 | 70.46477 | | | | | | | | | | |
| 13 | 27.5 | 87.81499514 | 79.34168 | | | | | | | | | | |
| 14 | 30 | 100.457251 | 89.16026 | | | | | | | | | | |
| 15 | 32.5 | 114.9195449 | 99.97528 | | | | | | | | | | |
| 16 | 35 | 131.4638979 | 111.8334 | | | | | | | | | | |
| 17 | 37.5 | 150.3900532 | 124.77 | | | | | | | | | | |
| 18 | 40 | 172.0409059 | 138.806 | | | | | | | | | | |
| 19 | 42.5 | 196.8087163 | 153.9446 | | | | | | | | | | |
| 20 | 45 | 225.142216 | 170.168 | | | | | | | | | | |
| 21 | 47.5 | 257.5547383 | 187.435 | | | | | | | | | | |
| 22 | 50 | 294.6335184 | 205.6787 | | | | | | | | | | |
| 23 | 52.5 | 337.0503324 | 224.8064 | | | | | | | | | | |
| 24 | 55 | 385.5736686 | 244.6989 | | | | | | | | | | |
| 25 | 57.5 | 441.0826503 | 265.2136 | | | | | | | | | | |
| 26 | 60 | 504.5829637 | 286.1871 | | | | | | | | | | |
| 27 | 62.5 | 577.225078 | 307.4402 | | | | | | | | | | |
| 28 | 65 | 660.3250895 | 328.784 | | | | | | | | | | |
| 29 | 67.5 | 755.3885658 | 350.0261 | | | | | | | | | | |
| 30 | 70 | 864.1378231 | 370.978 | | | | | | | | | | |
| 31 | 72.5 | 988.5431301 | 391.4612 | | | | | | | | | | |

Somewhere, there is a table with lots of numbers in it!
… and time can be a "slider" parameter to create moving diagrams

Example 1

Example 2

# Summary

- Aid to understanding simple, but non-trivial maths
  - Visualise equations/functions/calculations/trends
  - Excel "Activex controls" allow an intuitive interface
- Students report that these tools "close the loop"
  - Linking real phenomena ↔ mathematical descriptions
  - Ability to "fiddle the controls" harmlessly
- The first example took ages to construct
  - Subsequent examples much faster!
- They are all here … https://www.teaching.eng.ed.ac.uk/open-educational-resources