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Professor Hanington's Speaking of Science: The power of the positive exponential

GARY HANINGTON
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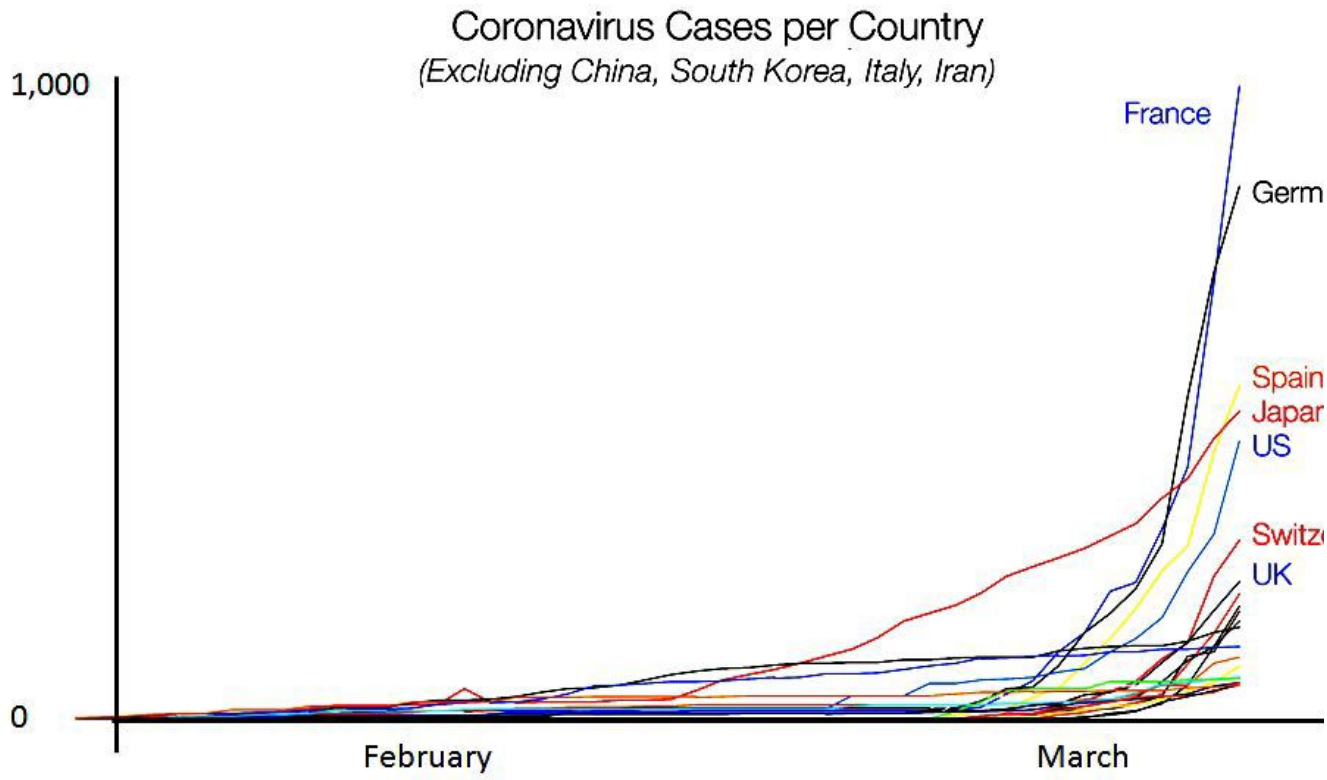

Chart of Covid-19 per country

TOMAS PUEYO

This week a lot of politicians and newscasters are saying the Chinese corona virus, Covid-19, is increasing “exponentially” in the world. Just last week there were 88 cases within the United States and now, as of today, March 12, there are 1,350. The fact that it seems to be doubling every few days can be modeled using

mathematics. This is handy because it tells us what the numbers will grow to as the days go on allowing hospitals and care facilities to plan what they will need to have to treat people in the coming days.

Because a great deal of physics can be explained by using the exponential function it is good to understand how it operates. You don't need much training in mathematics to use the "e to the x" button on your scientific calculator or I-phone. It is a friendly function. Students usually first see the exponential equation when taking calculus because it easily provides solutions to loads of differential equations that govern our world. For example, when you pour out a cup of tea, it cools off in temperature according to a negative exponential with respect to time:

Temperature = Tinitial e -kt

where k is some parameter that depends on the size and shape of the cup and the coefficient Tinitial is the starting temperature of the tea at time zero. Because the "e" function raised to a negative value is inherently less than unity the temperature of the tea will fall as time goes on. The negative "e" function is found everywhere in our world that include such diverse areas as chemical reactions to electronics to statistics. You cannot make a "bell curve" without it. It is interesting to ask why the exponential function has this ability to fit many physical systems and the answer is simply that the slope of the curve is equal to the exact value of the curve at any point. This strange behavior only occurs when e = 2.7182818... and was discovered by Leonhard Euler, the pioneering Swiss mathematician and physicist in the 18th Century.

Notice that the above temperature equation has a negative exponential. In fact, almost all systems use the negative exponential. The positive exponential function is rarely found because it “blows up” too quickly. Just try putting in “e” to the 231 in your calculator and it cannot even handle it. Consequently, the positive form is only used to model explosive situations, for example the explosion of gunpowder shooting a bullet or a chain reaction in an atomic bomb. When the technicians pulled out the control rods in the nuclear reactor at Chernobyl, Russia on April 26, 1986, (and had blocked the fail-safe pumps from coming on) the reactor jumped from low power to over 30,000 MW within a few seconds. This was a positive exponential if you plotted the reactor temperature as a function of time. The nuclear reaction released 40 billion joules of energy in the blink of an eye.

But I don’t want you to think that all positive exponential reactions are bad. There are a few positive exponential relationships can be modeled that are stable and inwardly beneficial to mankind. One of them is the approximation for continuously compounded interest:

$A = Pert$

When you put money, P, in an interest bearing account, the amount, A you will have increases exponentially with time. In this equation r is the rate and t is the time in years. If your ancestors had invested a penny in 0 AD, at the rate of 2% per year, it

would be worth about $ 3,511 trillion today. You would be three times richer than Jeff Bezos!

Another useful positive exponential function is the one involving friction of rope wrapped around a post. The amount of holding force, H, that can be applied to the rope without it slipping, increases as a positive exponential function involving the number of turns around the post, N:

$$H = eN$$

If, for example, you want to pull out an old tree stump with your truck, putting four turns around the stump gives you over seven times more gripping force than just two turns.

So, the powerful positive exponential can be both good and bad. Concerning the present virus outbreak in our country, it looks quite bad. If it continues unabated, and (according to data published in an article by Tomas Pueyo of Medium), the number of cases double every three days, the timeframe for 100,000 cases in the US is about March 31st and one million cases is April 10th. Plan accordingly.

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Weekly Puzzle

Weekly Puzzle: If your ancestors had invested a penny in 1776 and got a good return of 10% per year, how much would you have now?

Solution: $395 million

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