Coronavirus (COVID-19): trying to understand the information being supplied to the public

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Introduction (by Geoff)

It has been rather frustrating listening to statements on television about coronavirus (COVID-19) and what our responses to it should be, but often without clear explanations. What were the reasons for some of the recommendations? In consequence, we have developed what we believe could be a typical dialogue between a physics teacher and a biology teacher – 'a school staffroom chat', except that one of us is retired, we never worked in the same school and email has enabled us to do this while being many miles apart. The purpose is not to give an expert opinion but to try to help teachers in explaining this very unusual experience we have all had to face suddenly.

Dialogue

Geoff, the retired physics teacher: I am not a biologist. Biology was not done in many boys' grammar schools in the 1950s. It was introduced into my school at the start of my second year of teaching, in the mid-1960s. One twist that I recall was several colleagues starting to ask the new biology teacher for advice about looking after their gardens; eventually he said that garden plants were not his speciality.

I do believe, however, that I think scientifically. So, when we are given certain instructions, I like to know why.

I suspect that, like many, I had taken the coronavirus threat fairly lightly until early March. It was a problem somewhere else, but the availability of air travel on a large scale, and people being on large cruise liners all year round, seems to have created a spread far wider than anyone anticipated. This rapid spread in the last 3 months has made me start to think about questions to which I do not know the answers. If we were given clear reasons behind government advice, it would help. I wanted a biologist's view.

Neil, the biology teacher: I am not a virologist or an epidemiologist (nor an expert on garden plants). On the other hand, I have taught biology for over 25 years and recognise the importance of relating information to something understandable to turn it into knowledge.

Geoff: How could it apparently come from nowhere? Why does it have two names, coronavirus and COVID-19?

Neil: News reports seem clear that it started in a fresh food (including raw meat) market in Wuhan, China. Although there's slightly more to it, diseases are generally named by the World Health Organization (WHO) according to fairly strict rules (often after various names floating around the community). The virus itself is usually named by groups of expert virologists; this virus was originally called the 'novel coronavirus' in the UK. Coronaviruses are a large group of viruses that cause disease in animals and sometimes in humans. The name comes from the protuberances on their surface that appear to end in crown-like spikes. Every time a new variant is discovered it is novel until it gets its own name; this virus's official name is now *severe acute respiratory syndrome coronavirus 2*. It causes a coronavirus infectious disease first identified in 2019 (hence COVID-19), and because of the strong emotional connotations of calling the virus SARS-CoV-2, WHO is persuading all news agencies to talk about the 'virus that causes COVID-19'.

Geoff: Does this mean it is similar to SARS (severe acute respiratory syndrome), but authorities thought that the use of that name would spread panic unjustifiably?

Neil: Yes, exactly; this coronavirus is a closely related strain of the virus that caused the original SARS epidemic in 2003–2004, but this one doesn't cause the disease SARS.

Geoff: So what is it?

Neil: What is a virus? Viruses are organisms that lie part-way between living and non-living material. They are far smaller than bacteria and do not contain all of the necessary mechanisms to sustain independent life. They survive by infecting other cells, adding genetic material (RNA or DNA; this particular virus adds its RNA) to the cell in order to 'force' it to make many (perhaps thousands) more copies of the virus, which eventually rupture the cell, spreading the virus once more. On the other hand, many of us quite comfortably talk of 'killing' a virus whereas the correct term should probably be 'destroying' because a virus is technically not alive.

Antibacterial agents and antibiotics have no effect on viruses as they are not bacteria. It's rather like trying to kill a charging bull by squirting fly spray at it! Viruses cannot 'breed' on their own – they can only multiply within the cells of other organisms.

Geoff: How big are these 'creatures', if that's what we call them? There have been pictures on television indicating that they look rather like burrs (the seeds of some plants which have hooks in the ends of spikes that enable them to attach to animals and distribute over a wide area; Figure 1) or sea mines seen in World War II films (Figure 2), but the spikes on TV illustrations seem to have ends like rubber suction cups (see the front cover image of this March 2020 issue of the journal). More recently, I have seen illustrations in which the ends look like the florets of broccoli. They are blue and orange (but sometimes other colours). Can those colours be seen, or is it down to imaginative artists?

Neil: Viruses are all microscopic, typically of the order of 50–200 nm in size; see this video that illustrates the relative sizes of various microorganisms: https://youtu.be/h0xTKxblElU. Viruses are too small to have any colour – electron microscope scans often have false colour added so it is easier to distinguish different parts of the image.

Geoff: So it seems like the 'spikes' or protrusions enable them to cling to other cells?

Neil: The corona spikes on the surface of the virus match receptors found on the cell membranes of body cells in the lungs, arteries, heart, kidney and intestines. This allows the virus to latch on and enter the cells. This is the first coronavirus to have been discovered to have this mutation, which makes it more infectious (because it has a 'pass card' to get into the human cells).

Geoff: How deadly is it? Why can some people have no symptoms, some become ill to various degrees but recover, and some die?

Neil: The overall risk of death from COVID-19 appears to be between 1% and 3% or so. It is difficult to tell exactly, as so many people, particularly in the UK, are not being tested. Hence it is difficult to know how many people are not diagnosed with the disease, and yet recover. In Germany, the mortality rate is probably only 1% but in countries with less good health services it will probably be higher.

This rate compares with a risk of death from influenza of around 0.1%, or around 10% from SARS. Some people are at much higher risk than others, though, as the mortality rate is affected by the age and gender distribution of people in the country (males over 70 should take special care) and the general health status of the population. Those with a reduced, or compromised, immune system cannot fight the infection as well as healthy people. The other key thing is that some people who are infected will find it more difficult to cope with the symptoms. If you have lung or heart disease, the shortness of breath that the disease causes could be enough to kill you.

Figure 1 Burrs on a burdock plant, which inspired the invention of Velcro; image by WikimediaImages from Pixabay

Figure 2 A mine, possibly from World War II, apparently disarmed and being used as a float; image by klimkin from Pixabay

On the other hand, around 60–80% of cases appear to be asymptomatic (Li *et al*., 2020) yet are still at least 50% as infectious. It is these cases that are mostly causing the spread, which is why WHO recommends mass testing (Crisanti and Cassone, 2020). There is some discussion about whether the amount of virus in the body affects how severe your symptoms are (known as viral load), but studies are inconclusive at the time of writing.

Geoff: How does the virus affect the human body? Why does it make some people die yet allow others to recover without any signs of illness? Why does it cause symptoms such as fever, persistent coughing and loss of sense of smell or taste?

Neil: Worldwide, some 14–20% of cases are what is described as serious, and over two-thirds of these are in people with underlying health issues. How serious the illness caused by coronavirus is depends largely on how deep into the lungs the infection goes. If it remains high in the throat, you may get an annoying cough or just a slightly sore throat. This is usually caused by the cell debris from the cells that have burst during virus replication. If the infection descends deeper into the trachea or the bronchi, there will be inflammation alongside a high fever. The cough becomes more persistent and the patient becomes breathless easily. If the virus affects cells deep inside the lungs, the tiny bronchioles swell up, making the movement of air in and out of the lungs harder and putting a strain on the heart. A fluid is usually produced which can fill the alveoli (the regions at the ends of the tubes in the lungs where gas exchange occurs), and this is when pneumonia starts. There is a lack of oxygen getting into the blood and all sorts of complications can arise from this. This fluid is so deep in the lungs it cannot be 'coughed up', so sits and fills up the space where gas exchange usually occurs (Figure 3).

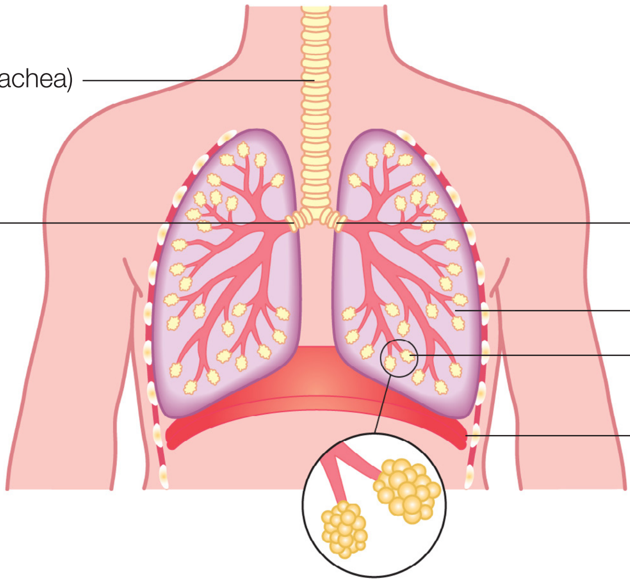

Figure 3 The respiratory system; image by Kathryn Nestor

The fever comes from your body naturally trying to 'fight off' the infection. A raised body temperature inhibits enzyme-controlled processes such as replication, which is why taking medicine to reduce body temperature, for example ibuprofen, can prolong any illness or make the symptoms worse as the virus replicates faster.

Geoff: A few months after starting school, I had measles; then a few months later, chicken pox. It seemed that everybody in our age group went through the same process spread across about 3 months from the first to the last. Each time, I was kept off school for 4 weeks, and clearly the attitude was, 'don't spread the infection' (though it seemed to spread anyway). Yet in more recent times, I have heard of groups of mothers organising chicken pox parties. The attitude is apparently, 'catch the illness and get it over with, because you can't catch it twice, and it is much less severe in young children'. That raises the question: 'Does the body develop an immunity to the infection, and, if so, does the immunity stay with us for life?'

Neil: That's an easy one to answer – we don't know! There is some anecdotal evidence that some people who have recovered from COVID-19 can get reinfected, but the accuracy of these stories is unknown and no longitudinal studies have been carried out.

We do know that with some viral diseases we do develop lifelong immunity, but with others, even if an immunity develops, it may be short lived. Other coronaviruses, such as some that cause the common cold, do induce an immunity, but it only lasts a few months. Of course, there are also many other types of viruses that cause a cold so even if we develop immunity to one, we can still catch a different cold.

Geoff: Presumably, it is ingested by breathing in, but then we breathe out and continue to spread it into the atmosphere. How long does it survive in the air? Does air temperature affect it?

Neil: In the early days of the pandemic, countries were looking to contain and delay the spread of the virus as there was a hope that in air temperatures above 20 °C it would not survive well. As the spring has worn on, that hope seems to have faded. Estimates of how long the virus can survive in the air vary widely and the data are just not clear enough to give a definite answer. It might survive for minutes, or for hours.

Geoff: The earliest and fastest spread outside China seemed to be in Italy followed by Spain, both regarded by the British as warm countries, although most of us who visit do so in the summer months. Perhaps the effect of temperature remains a puzzle. Body temperature is 37 °C.

Those of us who have worked in chemistry labs at school will have recognised how rapidly the release of hydrogen sulfide is noticed elsewhere very quickly. I also know that everyone is quickly aware of the additive released when a gas tap is left on at school or at home. These examples of diffusion can cover long distances, such as along a school corridor. Then what is so special about remaining 2 metres from other people? A significant proportion of what we breathe in must have been breathed out by somebody else. There is certainly not a 2 metre limit to the distance of 'air-sharing' in some situations. I would soon smell somebody smoking in a large crowded room and in the street, and that can be 10 metres away with many other people in the way.

Neil: I may be wrong, but I think the 2 metre separation is rather like the five portions of fruit and veg a day; in other words, it is something that is both easy to understand and easy to achieve in a particular country. Other countries have used 1.4, 1.6 and 4 metres as safe distances – it's more to do with not getting too close, not touching, and probably there is a scientific calculation along the lines of the inverse square law for particle concentration – the further apart you are, the lower the concentration of virus in the air, so the lower your chance of breathing some in. 2 metres is not a guarantee that no infection will occur but it is a point at which the government advisers have agreed the risk is acceptably low. So the long answer is that the 2 metre separation will be a culturally acceptable distance to do with the amount of moisture breathed out by the average individual in the average temperature and humidity conditions at a standard air pressure and the viral load within that moisture, which will depend on the viral load in the body of the infected person and the position of the infection within the airway. There is no exact answer.

In general, viruses do survive longest at lower temperatures, above freezing, and higher humidity; the humidity being the key point.

Interestingly, thanks to its pH and porous nature, human skin is a 'dangerous' environment for most viruses – they survive for only about 20 minutes on our hands (Griffin and Akpan, 2018).

Geoff: I can understand that fine droplets are given out in a cough or sneeze, but what about normal breathing? After some thought, I realised I might be able to answer my own question. I think it is well known that we breathe out carbon dioxide. I also know that much of our food contains carbohydrates and hydrocarbons. So we must also breathe out water but don't see it. However, when we breathe out on a cold morning in winter, we do see the evidence of this exhaled water. Growing up seeing trains from my house, I called this output 'steam', and as a young child believed what I could see coming from myself on a cold day must be the same. School science then taught me that steam (individual molecules of water) only exists above 100 °C at normal atmospheric pressure. Hence the water we breathe out has to be in very fine droplets. But they must be too small to see. Evidently it is these invisible droplets that carry the virus from an infected person. We also breathe out nitrogen and unused oxygen. Without that oxygen, mouth-to-mouth resuscitation would not be effective.

Neil: The water that we breathe out is in the form of vapour. In very cold conditions, some of this vapour condenses to form tiny water droplets, thus making it visible. The same sort of thing happens with 'dry steam', which is invisible, and 'wet steam', such as that from steam locomotives, which contains a mixture of vapour and droplets, and so is visible.

Coronavirus is spread in the liquid expelled when someone coughs or sneezes. These aerosol particles are then breathed in and may attach to the cells in the nose or throat – or may be trapped by the body's defences, mucus, and so on. This is why the guidance is to cough into the crook of your elbow. In general, it doesn't appear to be the case that the virus really spreads to an infectious level in the moisture that is breathed out, but 2 metres is a long distance away to smell someone's breath! Virus particles are much larger and heavier than any gaseous molecule so they do not float around in the air for more than a couple of hours before falling to the ground. This type of virus doesn't appear to cause sneezing, where droplets are often smaller and expelled with greater force. On average, liquid expelled through a cough doesn't travel further than 2 metres, although when it lands on the floor or a hard surface it can sit there for some time before it fully dries out. This is why there is the concern about cleaning down surfaces that other people have touched, or coughed on. A recent study (van Doremalen *et al*., 2020) found that the COVID-19 coronavirus can survive for up to 4 hours on copper, up to 24 hours on cardboard, and up to 2 or 3 days on plastic and stainless steel. There are some suggestions, though, that what is being detected are traces of a 'dead' virus rather than a viable, infectious organism.

Geoff: What effect do face masks have? Would a home-made one be any use? I have seen tourist groups from the Far East routinely wearing face masks on holidays in European cities.

Neil: Largely, face masks are not particularly effective except in a clinical setting where patients may well be coughing all over the clinicians. In the street, unless you expect someone to be coughing in your face, they are not much use. There are also different types of face mask with different particle-size filtering capabilities. A mask designed to stop sawdust particles getting into the nose and throat is not going to work as well on virus particles that are some 10 000 times smaller; rather like the different-sized holes in tea bags and coffee filters. Although the wearing of masks became almost ubiquitous after the 2003 SARS outbreak, the masks that many tourists from the Far East wear were originally designed to catch the large particulates in vehicle emissions. It has become something of a racial stereotype, but this has, sadly, become a racist issue in the current times, with some people talking of 'the Chinese virus' and others believing that anyone from the Far East must wear a mask to protect others!

Geoff: One of the key ways to reduce the spread is to 'wash hands vigorously under hot running water for at least 20 seconds, dry with a tissue and put it in the bin'. My first reaction was that 'germs' thrive better in warm water – why not use cold? The next thought was that viruses washed off would be going down the plughole – would we be contaminating our water management system?

I have read that a drop of rain that falls into the Thames at source in the Cotswolds will be drunk by eight people by the time it reaches the sea (www.living-water.co.uk/blog/interesting-facts-about-the-water-in-london).

Neil: Viruses, as with all cells, are surrounded by a membrane that is largely made up of lipids with some proteins embedded into it. Soap dissolves lipids – which is why we use it for washing up our greasy frying pans – and without a membrane to hold the virus together, it is destroyed. Washing with warm/hot water also helps to remove oils on the hands, which can trap particles, including disease-causing pathogens, so warm/hot water is a more efficient way of removing potential pathogenic organisms than cold water, which does not help break down oils on the skin as effectively.

Any viruses that have survived the soap are likely to be destroyed by the sewage treatment or have 'died' outside a host by the time the cleaned effluent is returned to the river. Similarly, most drinking water treatment is designed to destroy pathogens – either chemically, using chlorine for example, or by UV irradiation – so that is unlikely to be a source of contamination in westernised societies.

Geoff: Then what about a bin full of moist contaminated tissues? Surely a breeding ground for these contaminants!

Neil: Well, viruses cannot breed on their own, unlike bacteria, so they won't be multiplying but they may still be present. The waste in the bin would need to be carefully collected and disposed of. The virus particles may get into the air if the tissues are shaken around.

Geoff: Does this virus affect pets and farm animals?

Neil: Coronaviruses as a group do affect animals (remember humans are animals), but each individual virus is specialised to only cause disease in one particular species. Through mutation, it is possible for them to infect a different species instead – remember the outbreak of avian flu a few years ago? From the genetics of this particular virus, it is very similar to a virus that affects horseshoe bats but it mutated to infect, possibly, pangolins before mutating to affect humans. In its current state, it is unlikely to infect bats now. It is still mutating with at least five genetic variants noticed. These mutations are generally single bases and do not appear to affect its potency. What they may do is affect how quickly an effective vaccine can be produced as any vaccine needs, ideally, to stop all strains of the virus.

Geoff: Thanks! I now understand the information much better. Now we have to wait. It seems we shall not have reached the peak before this is published. We can't know whether summer holidays already booked might go ahead. Sadly, schools will not get the chance to enjoy the usual end-of-year activities, and those moving on will not be able to say proper goodbyes.

It is over 50 years since human technology enabled us to land on the Moon and return safely; and we can all communicate with people on the other side of the world in seconds. How could we let something as small as coronavirus cause such chaos and stress? Then I realised: viruses are too small for us to see; we cannot smell, taste, hear or feel them; and once they established, they quickly had us outnumbered.

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