CHAPTER 1

minute biocreatures

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The smallest of all creatures, yet the strongest…. they have withstood the test of time by being the oldest creatures on this earth. They were the first life forms to develop on the face of the Earth, some 3-4 billion years ago. They enabled the existence of free oxygen on Earth through photosynthesis, have braved extreme conditions including volcanic eruptions, several ice ages, continental drifts and mass extinctions. While many species including the great dinosaurs which have once walked the surface of this Earth have gone extinct, these minute biocreatures have certainly outwitted, outplayed and outlasted, emerging as the true survivors of the fittest.

Animalcules – the beginning

Microorganisms, commonly called microbes, are minute unicellular or multicellular biocreatures which are usually microscopic in size, so tiny that a microscope is needed to aid vision of these living cells. The study of microbes is called microbiology, a field of study founded by the first microbiologist, Antonie Philips van Leeuwenhoek, also fondly known as the “Father of Microbiology”. Leeuwenhoek, a draper (cloth retailer) who had an interest in lensmaking, used one of these lenses to design a microscope of his own. Using this microscope, he was the first to observe and describe single-celled organisms which he called animalcules in the 1670s. The term has since been recoined to microorganisms.

A Class of Their Own

Microbes can be roughly classified into five very large groups; archaea, bacteria, fungi, protista and viruses. Bacteria and archaea are prokaryotes, organisms that lack a cell nucleus and membrane-bound organelles. They are almost always unicellular and microscopic in size. Archaea and bacteria are very similar to each other and were previously classified in the same kingdom. However, it has since been known that they differ in terms of genetics and biochemistry so the current phylogenetic Tree of Life is a three domain system consisting of Archaea, Bacteria and Eukaryota.

With approximately 5×10^{30} bacteria, the biomass of bacteria exceeds even that of all plants and animals in this world. Under optimal conditions, they grow exponentially, doubling as fast as 20 minutes. They are usually only a few micrometres in size and come in all sorts of shapes such as spheres, rods and spirals. They are so ubiquitous, they can be found everywhere! Both archaea and bacteria are extremely adaptable microbes; they can live in extreme conditions. Volcanoes, the Arctic region and the deepest seas are some of the extreme places that these microbes can be found.

Fungi and protista are eukaryotic microbes. Fungi include yeast, moulds and mushrooms. Some are microscopic in size while others like mushrooms and moulds can be seen with the naked eye. A major characteristic which differentiates fungi from other living organisms are their cell walls which contain chitin, unlike cell walls of plants and some protists which contains cellulose while those of bacteria contains peptidoglycan. While fungi may look more plant-like as they can be found growing on soil, studies have shown that their genetic make-up is more animal-like. Protists are a diverse group of eukaryotic microbes which do not have specialized tissues, thus differentiating them from other eukaryotes such as fungi, animal and

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plants. They can be unicellular or multicellular and live in liquid-based environments. Finally, viruses, which may be the most abundant of all microbes, are sometimes considered non-living molecules as they require a live host to replicate and function. Still, the field of microbiology encompasses the study of viruses. Virus particles consist of the genetic material (DNA or RNA), a protein coat which protects the genetic material and sometimes an outer lipid layer which envelopes the protein coat when they are outside a cell. Outside a living host, viruses are just like air-borne particles, dormant and without life.

Friend or Foe

People usually associate microbes, especially bacteria and viruses with diseases. This is true as many deaths around the world are caused by infection of pathogenic microbes. In fact, many epidemics which could wipe out an entire population rapidly are caused by infectious microbes. However, many microbes are also commonly used to produce valuable products in our everyday lives. Even before any microbes were successfully isolated and identified, mankind have been using bacteria and fungi for fermentation in the food industry without prior knowledge of the role these microbes play in imparting flavour and preservation. For example, lactic acid bacteria (LAB) are used in the making of cheese from milk. The lactic acid produced by these bacteria lowers the pH and helps curdle the milk to solids. Wine, beer and other alcoholic drinks are produced by *Saccharomyces cerevisiae*, a type of yeast which produces alcohol and is also responsible for the rising of dough in bread-making through the production of carbon dioxide gas. Penicillin, the antibiotic which has saved thousands of lives since it was first discovered is produced by the fungus, *Penicillium* spp. Many industrial enzymes such as proteases and cellulases which are used in detergents and as digestive aid, respectively are also produced by microbes. These are just some examples of the usefulness and value of microbes to humankind. Even in our gut, there are trillions of bacteria, about ten times the number of human cells in our bodies. These gut bacteria largely confers health benefits to us especially in terms of defending our immune system. This is part of the reason probiotics are trending these days.

While examples given above involve naturally occurring microbes, in modern times, exploiting microbes have evolved to include biotechnology advances which allow human intervention in artificially incorporating the usefulness of these microbes. Recombinant DNA technology has allowed genes which encode a protein of interest from other organisms to be transferred into microbes, allowing these microbes to be small, powerful and industrious workhorses in producing valuable products. For example, human insulin used in the treatment of diabetes is currently produced by recombinant Escherichia

coli by cloning the gene which produces insulin from human into these fast-growing bacteria. Using recombinant DNA technology and genetic engineering, microbes have become live cell factories for production of human, animal, and plant products, cutting down cost, time and space needed to produce these products conventionally.

Microbe manager

A library is a place where books are managed; they are collected, kept, categorized, and people can come to read them and even borrow. However, how do you manage microbes? Firstly, they are living cells. Secondly, they are just so tiny. And thirdly, the vast variety of microbe species is simply confounding.

In UPM, the Microbial Culture Collection Unit (UNiCC) under the Institute of Bioscience (IBS), was first established in 2008 to be the main culture collection for UPM research and teaching. It provides services and expertise in isolation, identification, preservation, and quality checks of microorganisms, as well as allowing researchers to safe-keep their cultures in a systematic way, much like keeping books in a library. Microbial cultures are stored together with detailed information of the cultures in two ways, either lyophilized (made into powder form) or cryopreserved (stored at -80 °C) in sterile conditions to avoid contamination of other undesirable microbes. When a culture is needed by the researcher, they can be withdrawn from the culture collection, much like borrowing a book out of a library.

Since its establishment, UNiCC has now opened its doors to researchers from other universities, research institutions, agencies and industries in Malaysia. Additionally, services have extended to include antimicrobial assays. UNiCC has grown into an active unit organizing seminars/workshops to increase awareness on the importance of culture collection and conservation of biodiversity of microorganisms in Malaysia. UNiCC has been registered with the World Data Centre for Microorganisms (WDCM) since 2011.

In a Nutshell

Microbes – these minute biocreatures are indeed magnificent and amazing. Its diversity - a reminder of God's wondrous creation. Its size - a reminder of strength and greatness in smallness. Its ubiquity – a reminder that small miracles can be found everywhere. And its abundance – a reminder that there is great power and potential in numbers and unity. The famous quote "Out of sight, out of mind" is definitely not applicable to these minute biocreatures as microbes have weaved and embedded their ways into our everyday lives in ways we just can't ignore.

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jury review

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Abdul Munir Abdul Murad

The world of microbes is fascinating. They are very diverse and have an amazing variety of shapes and sizes and can be found in a wide range of habitats ranging from the sea ice in the Antarctic to the stomach of human bodies. Despite their prevalence, microbes could not be visualized until the invention of microscopes by Antonie van Leeuwenhoek at the end of the 17th century. The effects of microbes on our everyday life are tremendous. They can be harmful to human beings by causing various diseases such as AIDS, cholera, tuberculosis, rabies and cold, and destroying human food sources by causing diseases to animals and plants. However, the harmless and beneficial microbes far outnumber the harmful varieties. They are vital to humans for various reasons; most importantly, they participate in the Earth's element cycles and clean the Earth of remnants of dead organisms. Microbes are also widely employed by humans in the food industry, agriculture, biotechnology, pharmaceuticals, and bioremediation. Some of the natural microbial flora that reside in the human gut even provide protection against more virulent microbes.

Due to the importance of microorganisms in our daily life, the effort to showcase microorganisms in NYAWA'14 should be praised and credited. This lively and engaging exhibition displayed the importance of microorganisms in a contemporary context. The research outputs were elegantly and creatively presented in the forms of diagrams, pictures, graphics and artful handicrafts. It is useful for the curious individuals wanting to learn more about this group of fascinating creatures. The general public with no prior microbiological knowledge will find the research outputs presented in this exhibition easy to understand and may create the interest in them to know more about the microbial world.

The NYAWA '14 exhibition provides science-based information about important topics in which microbes, including virus, bacteria and fungi, play important roles. It illustrated the importance of microbes in the food industry, biotechnology, agriculture, and as pathogens causing diseases. Microbes have been used for hundreds of years in traditional food fermentation, even before people realised that microbes were behind the transformation processes. As illustrated in this exhibition, both preparations of "tapai" and "ikan pekasam" require fungi and bacteria to ferment the starting ingredients for a product with a different flavour, aroma and texture. With the advance in biotechnology and fermentation technology, this exhibition showed that microbes have been utilised commercially as probiotics in dietary foods and as a factory to produce enzymes, metabolites and vaccines which are useful for various applications.

Farmers often think of microbes as pests that are destructive to their crops, but many microbes are beneficial. Microbes can improve soil quality and health, and the growth, yield and quality of crops. Some soil microbes such as mycorrhizal fungi and nitrogen-fixing bacteria form symbiotic relationships with plant roots and provide plants with important nutrients like nitrogen or phosphorus. Microbes that live within plants are called the endophytes and can colonise the upper parts of plants and provide many benefits, including resistance to pests and plant diseases. NYAWA '14 exhibited

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B-green biofertiliser compost which consists of nitrogen-fixing and phosphate-solubilising bacteria. Likewise, the introduction to plant endophytes was displayed in a very interesting manner. The applications of these beneficial microbes to plants may reduce the dependency on chemical fertilisers which are primarily made from non-renewable sources and could cause environmental pollution if used excessively. Microbes, thus, play an important role in ensuring the fertility of agricultural soils for generations to come.

Microbes are one of the most successful life forms on earth and one of the reasons for their pervasive presence is their capability to utilise any available food source, including humans and animals whose defences may be breached. Human and animal hosts are nutrient-rich, warm, and moist environments, which remains at a uniform temperature. It is not surprising that many microbes have evolved the ability to survive and reproduce in these desirable niches. NYAWA'14 highlighted several human and animal pathogens, especially viruses such as poxvirus, human papillomavirus, herpesvirus, coronavirus, influenza virus, Newcastle Disease virus and the deadly Ebola virus. These viruses have caused several outbreaks worldwide, resulting in high death tolls. Researchers made an excellent effort to inculcate knowledge on how these tiny creatures invade the host body to cause infection.

In conclusion, the NYAWA '14 exhibition successfully disseminated information about the importance and influence of microbes in daily life. The information presented in this exhibition will lead us to a better understanding of what microbes are capable of doing. The more we learn about microbes, the more we appreciate what these tiny creatures can do.

Khatijah Yusoff

Microorganisms have important roles and functions in their respective ecosystems; many beneficial but a relatively small number can be harmful and even deadly. NYAWA '14 walks the audience through a journey in this fascinating world of microorganisms mixing art and rhythm with the science of microbiology. Against a backdrop of these normally invisible microorganisms and through their various shapes and sizes we can appreciate the roles and functions of the minute creatures. The exhibition highlights the good, the bad, and the ugly side of the microorganisms or microbes in short. In order to survive the variety of habitats, microbes have evolved a variety of metabolisms for energy, nutrition, and reproduction. Humans have ingeniously been able to control and utilise them in agriculture, energy production, medicine, industry, and even warfare.

NYAWA 14 explains these through art and play. Microbes degrade pollutants and by doing so clean up the environment. When they

decompose, they release nutrients back into the environment that are needed by plants and animals. Microbes have an important role in the cycling of many other compounds in and between ecosystems, utilizing oxygen, carbon, and nitrogen. Many microbes use the energy of sunlight to convert carbon dioxide to oxygen, which we need for respiration, and survive. As they do this, they create new organic materials which are then consumed by other organisms. In this way, the cycling of nutrients and energy continues, efficiently – there is no wastage in nature! We have learnt to use their natural metabolism to create new forms of food like tapai and ikan pekasam, fertilizers and feed - these are highlighted in NYAWA '14. How can the prebiotics, probiotics, and postbiotics help improve our health and nutrition? How do we use the microbes to enhance our fertilisers and animal feed? Truly these minute creatures have profound effects on our lives and surroundings.

Whilst trying to answer these questions, we cannot lose sight on how dangerous and very deadly microbes can be; poxviruses and the filoviruses and the current Ebola outbreak readily come to mind. However, not all viruses are bad. For instance, the Newcastle disease virus is deadly to chickens and can potentially decimate our poultry industry - but it brings promise to the cancer patients worldwide. It has the potential of an anticancer agent. Other viruses like influenza virus and coronaviruses can be manipulated and be utilised to protect us from their deadly consequences. Bacterial viruses called phages can be used to control the bacteria.

There are now many ways to genetically manipulate and alter their DNA to create compounds that the microbes would not normally produce. They can act as microbial cell factories to produce vitamins, enzymes, drugs, and chemicals. Insulin, which is used in the treatment of diabetes, is now being produced by the microbes. They can also be used to produce alternative fuels. Microbes are also used to change the DNA sequence of other organisms, thus enabling plants to become resistant to insects and viruses. The interaction between *Aspergillus*, *Fusarium, Cladosporium* species and other fungi in the gaharu trees (*Aquilaria malaccensis*) to produce oudh which is a major component in the million dollar perfume industry is portrayed. At NYAWA 14 the artform and rhythm depicted by an umbrella with the unique arrangement of ampoules captures the importance of systematic organisation and uniformity in the midst of chaos in the management of the microbial culture collection at UNiCC. By staining the bacteria, we are able to distinguish them based on the physical properties of the cell walls. The colourful pigments by the bacteria can also help in distinguishing them from one another. The shapes and different conformations of the bacteria seem to remind us of the various fruits.

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However, the structures of the microbes cannot be better translated than through the cross stitches of fungal mycelial threads and the photo montage displaying the images from powerful microscopes. These interplay of images on the ultrastructure of the miniscule microbes conceptualizes their complexity. What do microbes and dinosaurs have in common and why does the chick cross the road? Answers are available if you visit NYAWA '14. Microbes prove that size indeed does not matter, in a sense, but in another it does indeed matter.

Jeannette Goon Chern Yuet

The world around us is crawling with life and there are trillions surrounding us, unseen. They live on the surfaces of our work tables, in our waters, on our skin. That's right, they are microorganisms.

When I was told that this year's NYAWA had a focus on these microscopic creatures, I was excited. I have always been fascinated by these tiny living things that may be small, but can produce such immense effects, sometimes helpful and other times so harmful. The idea of science being used to produce art delights me and I wondered if Malaysian scientists would create art pieces as fascinating as the bacteriographs that American microbiologist Zachary Copfer had produced. I was not disappointed.

There are art pieces that highlight the roles of different kinds of microbes -- from fungi that help to develop the Gaharu aroma, bacteria that produce enzymes for biofuel production, to viruses that potentially be anti-cancer agents.

And with a range of pieces -- from images to installations -- the NYAWA exhibition should prove to be an interesting one. There are about 27 pieces to be exhibited this year and like any individual, I have my favourites.
The lantern modelled on the structure of the Influenza virus would definitely make my list. The artefact, if improved to its finest form, is a functional lamp that could find its place in a well-designed concept home or cafe. At the same time, it causes one to question how something with that level of aesthetic pleasure could be so deadly.

Another artefact I could see displayed in actual interiors is the framed calligraphy pieces produced using Gram-stained bacteria. In 1884, Danish scientist Hans Christian Gram developed the Gram staining technique to make bacteria in lung tissue more visible. This technique was later used to differentiate different types of bacteria based on their cell wall structure.

130 years after its development, and despite its limitations, this technique is still being used in laboratories for identification

of bacteria and quick diagnosis of infections. To me, this is an example how one scientific discovery can be developed into another, then lead on the other discoveries. This is a kind of beauty as well.

I also find myself incredibly attracted to the abstract interpretation of the molecular structure of cellulase, an enzyme produced by microbes. This enzyme possesses the ability to transform energy from plants into biofuel, a possible replacement for our world's depleting fossil fuels.

The picture features interlocking lines and squiggles within a circular-shaped border, imitating the actual structure of the enzyme. But at the same time it seems to be exploding out of itself as if to suggest at its potential as a producer of energy.The artist, in his statement, even highlights that fossil fuels were produced from dinosaurs --the largest organisms on the surface of the Earth – and that now, this role would have to be assumed by the microbes, "the smallest form of living organism".

As a writer with an interest in science, I am always enthusiastic about programmes that blend the arts and sciences. Programmes like these will, hopefully, increase the discourse on both the fields and allow artists and scientists to collaborate more with each other. This injection of differing perspectives would be beneficial to both fields.

While the arts have generally received more "publicity" compared to the sciences, in terms of reviews and providing updates to the general public, programmes like NYAWA would surely make science more accessible and interesting to non-scientists.

I would definitely like to see more programmes like these, but also for individuals to explore fields outside their own, without having to wait for a programme. Artists can certainly draw inspiration from science and scientists could develop their creativity through the arts.

For NYAWA specifically, I hope to see more interesting works of art in future years, with artist statements that have been well thought out and structured in a way that will provide viewers with better understanding or the science behind the artwork.

There is so much more that we can do if we do not limit ourselves to only one field.

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