Review of educational resource "Year 11 Science Workbook", NCEA Level 1, 2005, ESA Publications (NZ) Ltd.

Review panel consisted of members of the New Zealand Microbiological Society (special interest group in Education).

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Educational resource:

AME Year 11 NCEA level 1 workbooks are write-on booklets used by many secondary schools in New Zealand. The level 1 Science booklet contains a reproduction of the Science achievement standards as well as actual NCEA questions from the 2002, 2003 and 2004 external exams, including model answers justifying the awarding of grades (Achieved, Merit, and Excellence) and brief revision notes. Many schools are attracted to the affordability of the series ($15 each for 5 or more copies ordered) and hence the AME text is becoming the standard textbook at this level. Study guides are also available from the same publisher that contain "full coverage and understanding of all the level 1 science achievement standards", that is, those standards internally and externally assessed. The workbook revision notes are essentially condensed versions of the information in the study guides.

Methodology:

Christine Fenton received a complimentary copy of the publication, and contacted the publisher Mark Sayes regarding some errors of fact that she found in the workbook. The publisher agreed for her to send the manuscript to other members of the NZMS to review and see if they agree with her comments and then to provide him with the overall report.

One section only of the book of interest to the author was found to contain many errors and so the review was restricted to this section, namely "Achievement Standard 90188 – Describe aspects of biology (externally assessed 5 credits)". This was appropriate as the aspects of biology were mainly microbiology, cell biology and genetics.

Copies of the section of the workbook were distributed to all members of the review panel and they replied to Christine Fenton with their marked up copies and often an attached summary of errors.

The panel of reviewers included tertiary lecturers, secondary teachers and microbiologists in industry to ensure that the review panel had appropriate content knowledge and an understanding and experience of the teaching and examination of the different NCEA achievement standard levels.

This document is the resulting compilation of all the reviewers' comments and recommendations for improvement. Many items of grammar were also picked up but these shall only be referred to if it contributes to the confusion of information.

Review:

Bacteria

1. *Paragraph 1, sentence 2:*

"There are three main groups of micro-organisms – bacteria, fungi, viruses."

MAIN ISSUE:
It is inappropriate to say that there are three main groups, as there are more microorganisms than these three listed (e.g. protozoa, algae) that are just as "main" or important. The panel feels that this statement is misleading and a gross oversimplification, suggesting instead that "three of the main groups of microorganisms are:" if the other groups are not to be incorporated. Another alternative is to explain that "Bacteria represent one group of microorganisms" with other types being listed as examples and having no referral to "main groups".

It is important that this concept of "main groups" is not confused with taxonomic or classification "kingdoms". In microbiology, we do not use the 5 Kingdom approach commonly used in High Schools (Kingdoms of: Monera, Protists, Animals, Plants and Fungi). We use 16s rRNA sequences for classification of microorganisms, the use of terminology such as *Monera* and *Protist* is extremely outdated. However, when identification of unknown organisms is attempted, we do loosely categorize types or "main groups" of microorganisms as bacteria, fungi, virus, algae, protozoa, and others. This does not represent Kingdoms as there are **NO** phylogenetic kingdoms of bacteria, virus (nonliving), algae NOR protozoa recognized by microbiology.

MINOR ISSUES:
Microorganism is not hyphenated. Sentence should have "and" between fungi and viruses.

2. *Paragraph 1, sentence 5:*

"Large numbers of bacteria are seen as greasy coloured (white, cream, yellow, orange) spots or colonies when cultivated on nutrient agar."

MAIN ISSUES:
Colonies are NOT "greasy coloured" ("greasy" is not a colour). They can be dull, matt, shiny, glossy etc but greasy is inappropriate. Different microorganisms produce different coloured colonies. Recommend statement to read: "The bacteria grow on agar as colonies that contain many individual cells. These colonies appear as spots of varying size, shape and colour, depending on the microorganism".

"Nutrient agar" is a specific type of nutritive medium. Not all microbes capable of cultivation in a laboratory environment can be cultivated on nutrient agar. Recommend statement "Bacteria may be cultivated in the laboratory on agar plates containing nutrients necessary for their growth."

MINOR ISSUE:
Many microorganisms are not grown on agar plates, but in broths – the same nutritive medium without the agar to solidify it. The microorganisms then do not produce colonies at all. In the natural environment (agar plate is unnatural) most microorganisms grow on surfaces in the form of biofilms (tooth plaque etc). These are important fundamental microbiological issues and the panel feel that they deserve mention, although it is understood that agar plates and hence colonies are probably the most likely means to grow cultures in class at this level.

3. *Figure 1- Typical structure of a bacterium…*

MAIN ISSUE:
Bacterial DNA is **never** linear as depicted in this figure (represented as strings of chromosomal material). The nuclear material in a bacterial cell is a closed, circular loop of DNA often coiled (super coiled) into a ball. A more appropriate representation would be to depict the DNA chromosome as a squiggle (as in NCEA level 1 Biology and Human Biology Study Guide, ESA Publications). **This is an extremely important, fundamental issue relating to cell biology and must be corrected.**

The bacterial cell depicted has a capsule. This is not a common feature of every bacterial cell so to have it on this diagram labelled "typical structure" is inappropriate. Many important pathogenic bacteria do have a capsule but it is not "typical" of every bacterial cell. Another feature in this diagram is "flagellum": in particular three of them. They are too short, and again feature three (why three?) on one side only as "typical". This is not.

It is recommended that the diagram is redrawn with the nuclear material correct and that there is mention that some bacteria can have other structures such as capsules, and flagella. The basic "typical" bacterium would have a cell membrane, a cell wall, cytoplasm and a closed, circular chromosome. A figure cut in half with the "basic" components and then the other extras may be appropriate.

MINOR ISSUE:
Many bacteria do not exist as the "typical cell structure" implies. Many will exist in chains or groups – many individuals joined together.

Some mention of the approximate size of this cell would be valuable information to a student (~1 micrometer in width) or an indication of magnification.

The shape of this "typical" bacterium is known classically as a "rod" shaped – brick like (bacilli). Bacteria are commonly rod shaped **OR** spherical (cocci).

4. *Bullet point 3:*

"Cell Wall – maintains the shape of the bacterium. Some bacteria have a slimy, protective layer called a capsule, some have flagella which help with movement."

MAJOR ISSUE:
Bacteria can be protected by a HARD, RIGID outer layer called a *capsule*, OR a soft, slimy, slippery layer called a *slime layer*. The two structures are being mixed up here. Essentially, bacteria can have another polysaccharide layer external to the cell wall that protects it – if it is hard we call it capsule, (colony is often shiny): if it is slimy – we call it a slime layer (colony is often slimy). The proper word for this outer layer is glycocalyx. Many bacteria may have the extra layer but the presence of a rigid, organized glycocalyx layer (capsule) is not typical. See issue number 3 (above) for further information and recommendations on the capsule and flagella.

MINOR ISSUE:
The cell wall is also a very important way that microbiologists differentiate between different bacteria (via Gram reaction/stain). The slightly different way that the two types of walls are constructed (Gram positive and Gram negative) can mean different antibiotics can be effective or not against the bacterium. Knowledge about bacterial cell wall structure is fundamental microbiology. Some mention of its importance and the two different types may be appropriate.

5. *Paragraph 3, sentence 2.*

"Most bacteria are aerobic, requiring oxygen for respiration."

MAIN ISSUE:
Most bacteria do NOT REQUIRE oxygen but will use it if it is available. SOME bacteria require it, but MOST bacteria are "facultative" not "aerobic" - they will use oxygen if it is available, but they can also undergo anaerobic respiration.
This sentence could be rewritten replacing "requiring" with "using" and replacing "most" with "many".

6. *Paragraph 3, sentence 5.*

"….produces alcohol and carbon dioxide ….. baking and brewing industries"

MINOR ISSUE:
Mention of the production by anaerobic respiration of lactic acid which is important in the dairy industry in the production of dairy products (lactose milk sugar converted to lactic acid in yoghurt and cheeses etc).

7. *Paragraph 5, sentence 1.*

"….especially in warm conditions (30-40^{o}C)".

MAIN ISSUE:
Bacteria do reproduce at their most rapid rate nearest their optimum growth temperature (almost the warmest they can tolerate). For many bacteria that cause human illness (and animals) that happens to be between 30 and 40^{o}C and it is NOT

appropriate to say that bacteria reproduce most rapidly at this temperature as many would not. It is recommended that this sentence refers to this temperature range as being important for human diseases i.e. "*30-40^{o}C for human bacterial disease organisms."*

8. *Figure 2 – Growth phase diagram.*

MAIN ISSUE:
The first part of the growth curve is NOT the exponential growth phase as labelled.

The most typical terminology for a bacterial population growth curve should be used. In particular, the first initial part of the curve (flattened section of dark area of curve) should be labelled as the "lag phase". The rest of the dark area showing increased population growth should be "log phase" OR exponential growth, where the population is doubling in numbers as fast as its generation time, until numbers begin to reduce (flattening off of curve) known as the "stationary phase" until the die off "death phase".

9. *Table of Helpful vs Harmful bacteria*

"Examples of bacterial diseases in humans include throat infections, salmonella…"

MAIN ISSUE:
Salmonella is not the name of the disease – it is a genus of bacteria. The name of the disease (food poisoning) caused by some species of *Salmonella* is salmonellosis or *Salmonella* food poisoning.

QUESTIONS – BACTERIA

It is understood that these questions are not written by the author of this workbook but by NZQA examiners. Hence, these issues will be raised with NZQA but for the purposes of completeness, they will be included here. However, it is anticipated that this workbook's interpretation of the answers given by NZQA can be improved.

10. *Question One: Culturing Bacteria*

MAIN ISSUE:
This question has a defined contextual issue, that is; nutrient agar plates (a defined type of medium) inoculated with samples from a kitchen bench, and incubated for six days (why so long?). As this question is so defined and contextual instead of generalized (as in, two agar plates are inoculated with a sample and incubated at two different temperatures) then the given answers are **not correct.** With this given example it is not possible that you could deduce that plate A was incubated at 50^{o}C. Not all bacteria prefer the temperature range of 30 - 40^{o}C as this question is attempting to imply. In the answers relating to this question, there is the statement:

"*50 ^{o}C is too hot for bacteria."* This is incorrect.

It is understood that the purpose of this question is to test the students' knowledge regarding the conditions (i.e. temperature) that would be required for the growth of bacteria however; the panel have concerns that **students who had a very good understanding of this contextual issue would be penalized if they put a**

factually correct answer. Students who had a superficial understanding would achieve this question with an incorrect answer.

A better example would be a throat swab is taken and incubated at two temperatures – as the bacteria expected on the throat do prefer the 30-40^{o}C range and the human commensals have a narrow temperature tolerance you would expect a result like this: 25^{o}C : few colonies; 37^{o}C : many colonies; 55^{o}C : few colonies.

11. Question Two: Winter Colds and Flu

Faguele went to the doctor with a sore throat. A sample from his throat was cultured on nutrient agar to see if bacteria caused the problem.

MAIN ISSUE:
Winter colds and flu are not caused by bacteria so this question, which is testing the students' recall of bacterial structure, has an inappropriate heading.

The answer relating to this question has the "typical bacterial cell" which has the following errors as pointed out earlier in the review namely:

- Inappropriate depiction of nuclear material
- Use of capsule/flagella as typical
- Unrealistic depiction of flagella (too short, why three?)

Also, due to the contextual manner that this question is posed, that is, "a sample from his throat was cultured on nutrient agar …." the figure outlined in the answers is incorrect. The bacterial morphology expected from a throat swab is a cocci (spherical shaped cell), not a rod (brick shaped) as shown, with no flagella.
This question also implies that it is possible to deduce the cell morphology of bacteria by placing a sample on an agar plate. In reality, to examine a bacterial cell, the sample would be viewed under the microscope. By sampling and placing the sample on a nutrient agar plate, the student would not be able to ascertain the shape of the bacterium.

Question four: Growing Micro-organisms

MAIN ISSUE:
It is very difficult to conclusively say from this question that the colony pointed out in plate C is bacterial (as answers expect). A yeast colony could easily grow under these conditions after three days and would look similar to a bacterial colony on an agar plate. Then, the answer would be fungi.

If the question was to say that the plates were incubated for only one day, it would increase the likelihood that the colonies on plates C were bacterial, as yeasts (and fungi) are slower growing organisms.

It is understood that the question is attempting to test the students' knowledge of basic colony morphology comparing fungi (often filamentous colonies) and bacteria but this question does this poorly. The comparisons and expected answers relating to temperature have been discussed in "question one" above in this review document. There are other reasons other than temperature that would explain more colonies on plate D.

A student who had a very good understanding of this contextual issue would be penalized if they put a factually correct answer. Students who had a

superficial understanding would achieve this question with an incorrect answer.

12. Question Five: Antibiotics

MAIN ISSUE:
This question is attempting to show zone of inhibition studies and as such, the expected answers are difficult to arrive at with the depicted squiggle of bacterial growth. The bacterial growth on the agar needs to be confluent across the entire plate (a lawn) of bacterial growth. With this squiggle of growth you would not get zones of inhibition that would allow you to compare the results adequately. As it stands, to show that one antibiotic is "more appropriate than the other for this bacterium" you would expect larger zones of inhibition around the discs for the antibiotic that is most appropriate. With this squiggle, this would be difficult as the line does not go either side of disc C, so the student would not be able to tell if the growth is inhibited about the disc, or not. The wording "*If A is a better antibiotic than B*" should be clarified to "if A is more appropriate than B for these bacteria".

It is understood that the question is attempting to examine the students' understanding regarding antibiotics and their ability to inhibit bacterial growth and that not all antibiotics are appropriate against all bacterial species. If the squiggle is the most visual way of clearly indicating bacterial growth it is suggested that the squiggle is denser, and drawn to the edges of the plates to remove the difficulty with interpreting disc C.

Fungi and Viruses.

13. Figure 1 – structures of Fungi

MAIN ISSUE:
This figure is drawn and labelled incorrectly. It is assumed that this figure is representative of the "mushroom" type of fungi as the asexual reproductive structures appear shaped like a mushroom. If it is meant to be a "mushroom" representation there should not be "sporangium" nor should there be spores inside the mushroom cap. The figure as depicted in the text is absolute fiction.

A mushroom has a dense cap made of hyphae, with gills. On these gills are microscopic spores which appear like dust. The reproductive structure commonly found in mushrooms and toadstools is **never** called "sporangium". A mushroom does not have its cap filled with spores as this figure depicts.

If the structure is trying to represent the "mould" type of mushroom, the reproductive structures are represented incorrectly. Filamentous moulds appear as the "fuzzy patches" that the text is referring to and they have asexual reproductive structures that are only visible by use of a microscope. Many species have them shaped like balls containing microscopic spores and these structures are called sporangium. However, many species have the spores emerging off the end of a specialized hypha, a structure that looks similar to a bony hand. This structure is called a conidium (conidia, plural).

It is recommended that this figure is redrawn to either represent the mushroom/toadstool type of fungus with reference to sporangium deleted OR drawn to represent the mould type of fungus with reference to sporangium and conidia (and

an indication of size or magnification included). It may be simpler to call the asexual reproductive structures "fruiting bodies" or "asexual reproductive structures".

14. *Bullet point 4*

"Appear as fuzzy patches of white, green, orange or grey".

MAIN ISSUE:
Moulds or filamentous fungi may appear as fuzzy patches and in far more colours than is listed. Prefer a reference to a variety of colours. Mushrooms/toadstools are not a type of fungus that appear as "fuzzy patches" nor do the yeasts.

15. *Bullet point 5*

"Can be cultivated on nutrient agar".

MAIN ISSUE:
As explained previously in this review, nutrient agar is a specific medium. It is not routinely used to grow fungi. Rewriting this to "can be cultivated in a laboratory on agar plates" would be more appropriate.

16. *Bullet point 6*

"….sporangia (reproductive structures) containing spores. Mature sporangia burst open releasing huge numbers of spores….."

MAIN ISSUE:
As discussed earlier in this section, sporangia/sporangium is a specific asexual reproductive structure relating only to some species of filamentous moulds. Reference to sporangia in a generalized way should be avoided. Reference to "fruiting bodies" or "asexual reproductive structures" is more appropriate.

17. *Bullet point 1 – section on Viruses*

"Very simple forms of life…."

MAIN ISSUE:
Viruses are not forms of life. The first sentence is an oxymoron – "form of life that does not feed etc". They are essentially particles that contain genetic material and protein and are capable of existence within a host cell as an obligate parasite.

18. *Bullet point 3*

"Always cause harm – all viruses are pathogens".

MAIN ISSUE:
Viruses are obligate parasites. Parasite is a more appropriate term.

19. *Bullet point 4*

"…..destroy these cells in the process."

MAIN ISSUE:
Many viruses do destroy the cell in the process of reproduction however many viruses also do not. They are shed by various mechanisms that may not involve the destruction of the cell. Recommend the word "often" or "many" to show this.

20. *Bullet point 5*

"….diseases including …….polio, HIV…."

MAIN ISSUE:
HIV is the name of the virus, not the disease. The disease is AIDS.

21. Paragraph section on viruses
"Viruses are made of two parts – a piece of genetic material (DNA)……the contents of the host cell are used to make many new virus cells".

MAIN ISSUE:
Some viruses are not made from "a piece" of genetic material but many pieces, and often the genetic material is NOT DNA. A common example is the influenza virus that has 8 segments of RNA as its genetic material. This should be rewritten to "genetic material (RNA or DNA) and a protein case/coat."

Viruses are not cells; therefore, the host cell can not make "new virus cells". More appropriate terminology would be: "many new viral particles".

22. Figure 1 – structure of a virus

MAIN ISSUE:
The structure of this virus is incorrectly labelled. The protein case should refer to just the head of this particular virus and the item labelled as "protein case" in the diagram is actually the sheath. The tail fibers on this virus should be labelled and the tail plate is missing.

This is a typical representation of a virus that affects bacteria – known as a bacteriophage. It does not affect animals or plants and is only parasitic to bacterial cells.

QUESTIONS: FUNGI AND VIRUSES

*23. Question b: …. A **labelled** diagram may assist your answer.*

MAIN ISSUE:
The answer in the back of the workbook for this answer shows mushroom-like reproductive structures. Due to the contextual manner that this question is asked "describe how athlete's foot fungus feeds…" the correct diagram should not have mushroom-like reproductive structures, but microconidia (athletes' foot species produce micro-conidia). It is not clear from the marking criteria/model answer if a student would lose marks from this question if they represented the reproductive structures correctly (as microconidia) instead of sporangia or mushroom structures. So, it is anticipated therefore that the important information was the nutrient absorption.

24. Question Two: Glandular Fever
*"…..a **labelled** diagram may assist your answer."*

Answer in back of workbook "Virus attaches to host cell. Genetic material from virus enters host cell……" and associated figure.

MAIN ISSUE:

Again, because this question is specific in that the question has the contextual basis of “glandular fever” then asks the student to describe the process of viral reproduction, the model answer is wrong.

Glandular fever is in fact caused by Epstein-Barr virus which is an enveloped icosahedral virus (hence looks nothing like the depicted virus which is in fact a bacteriophage, not glandular fever virus, and does not affect human cells). The envelope on the Epstein-Barr virus fuses with the cell and the whole virion enters the cell (it does not inject its nucleic acid into the cell as diagram depicts). The virus is not released by cell lysis, but they bud from the nuclear membrane and exit via the endoplasmic reticulum.

So, in this question, the model answer diagram and associated description is entirely incorrect.

If the intention of this question is to allow the students to show that they understand bateriophage replication (nucleic acid is injected into the cell etc) then this model answer is still incorrect as the cell the virus is infecting is eukaryotic (has nuclear membrane) and bacteriophage are NOT capable of infecting this type of cell. The depicted virus (as earlier in the text as: *structure of a virus*) is only able to infect bacterial cells. If this question is to be contextual, as in a virus that is possibly familiar to the student is to be used as an example, then the whole section on viral reproduction and structure needs to be entirely rewritten. Mammalian viruses on the whole affect a cell in a similar way to the Epstein-Barr virus (generalized) that is, they fuse with the cytoplasmic membrane and the whole virion then enters the cell (not just the nucleic acid as bacteriophage tend to). Often, (depends on the virus) the new viruses are released by budding and not by lysis.

A student who had a very good understanding of this contextual issue would be penalized if they put a factually correct answer. Students who had a superficial understanding would achieve this question with an incorrect answer.

25. Question b: Glandular fever.
“Explain why it is not possible to culture a virus on a nutrient agar plate in a school laboratory.”

MAIN ISSUE:
If this question is relating to glandular fever, then the answer is correct (except for the reference regarding plants). Glandular fever virus CAN NOT be grown on nutrient agar (a specific medium, see earlier in the review). However, if the question is relating to viruses in general then the answer is incorrect.

The answer “*Viruses only reproduce in the cells of living plants and animals”* is incorrect. Viruses reproduce in cells of living organisms – that is, plants, animals and MICROORGANISMS (including fungi, bacteria, protozoa and algae).

“*Nutrient agar is not made of living cells, so virus will not reproduce in agar*” is correct but misleading. The viruses that reproduce in the cells of bacteria (bacteriophage) are grown in nutrient agar that contains the bacterial host cells. The virus is then put onto the agar plate and it utilizes the bacterial cells held in the agar medium (nourished by the nutrients in the nutrient agar plate). Hence, if the intention of the section was to instruct the student on bacteriophage (expected mode

of reproduction and structure implies this is the case) then those viruses are routinely cultivated on/in nutrient agar (with added host cells). Mammalian viruses and plant cells are grown in tissue culture.

26. Question five: Viruses as Parasites
"Viruses are known as obligate parasites. This means that they can ONLY live as parasites, causing diseases in plants and animals."

MAIN ISSUE:
As mentioned in previous sections, viruses also infect bacteria and other microorganisms. This is extremely important in the New Zealand Dairy industry where bacteriophage (viruses that infect bacteria) affect the starter cultures needed for the production of dairy products. As "disease" has also a specific meaning, not all viruses cause disease but they are parasitic.

This statement should be rewritten to: "infecting plants, animals and microorganisms."

27. a … "….draw and label a diagram to show the structure of a virus".

MAIN ISSUE:
The protein case should refer to just the head of this particular virus and the item labelled as "protein case" in the diagram is actually the sheath. The tail fibers on this virus should be labelled and the tail plate is missing.

This is a typical representation of a virus that affects bacteria – known as a bacteriophage. It does NOT infect animals or plants and is only parasitic to bacterial cells. Since the question begins with the statement "causing diseases in plants and animals" and does not mention bacteria, then the diagram given to show the structure of a virus should not be a bacteriophage, but an animal or plant virus (which has a different mode of replication and different structure from the model answer).

28. b – model answer
"They reproduce by invading the cells of plants or animals (hosts)…….this causes the host cell to die and burst open …….the cells of the host plant or animal."

MAIN ISSUE:
As mentioned previously, bacteria are susceptible to viral invasion (and all the examples in this publication are describing these viruses, not those of animals or plants). This statement could be rewritten by replacing "cells of plants or animals" with simply "cells of the host organism". Often, (as in the case of many mammalian viruses), the viruses do not kill or burst open the cell.