1.

I.

Genera	Nitrosopumilus	Nitrosophaera	Nitrosomonas
	Nitrospira	Nitrococcus	Nitrobacter

II.

Base on their primary functional traits as indicated in the figure

$$\begin{cases} \text{Ammonia oxidizers} \begin{cases} Nitrosopumilus \\ Nitrososphaera \end{cases} \\ Comammox(one-stepnitrification)\{Nitrospira \\ \text{Nitrote oxidizers} \begin{cases} Nitrosomonias \\ Nitrococcus \\ Nitrobacter \end{cases} \end{cases}$$

III.

Microorganisms	Nitrosopumilus	Nitrosophaera	Nitrosomonas
Domain	Archaea	Archaea	Bacteria
Phylum	Thaymarchaeota	Thaumarchaeota	Proteobacteria

Microorganisms	Nitrospira	Nitrococcus	Nitrobacter
Domain	Bacteria	Bacteria	Bacteria
Phylum	Nitrospirae	Proteobacteria	Proteobacteria

IV.

Genera	Nitrosopumilus	Nitrosophaera	Nitrosomonas
Morphology	Rod	Coccus	Spirillum
Genera	Nitrospira	Nitrococcus	Nitrobacter
Morphology	Spirillum	Coccus	Coccus

b.

Group 1

$$NH_4^+ + \frac{3}{2}O_2 \rightarrow NO_2^- + H_2O + 2H^+$$

$$\triangle G^0 = -2 \times 39.8 - 237.2 - 37.2 + 79.4 + \frac{3}{2} \times 0 = -274.6\ kj/mol(NH_4^+)$$

Group 2

$$NO_2^- + \frac{1}{2}O_2 \rightarrow NO_3^-$$

$$\triangle G^0 = -111.3 + 0 + 37.2 = -74.1\ kj/mol\ (NO_2^-)$$

Group 3

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + H_2O + 2H^+$$

$$\triangle G^0 = -2 \times 39.8 - 237.2 - 111.3 + 79.4 + \ 2 \times 0 = -348.7kj/mol\ (NH_4^+)$$

c.

According to my calculations, this Santoro's statement.

2. Culture dependent Approach

Methods: Enrichment Culture Microbiology

Classical Procedures for Isolating Microbes

Selective Single-Cell Isolation: Microfluidics

High-Throughput Methods

Culture independent Approach

Methods : General Staining Methods

Fluorescence In Situ Hybridization (FISH)

PCR Methods for Microbial Community Analysis

Microarrays for Analysis of Microbial Phylogenetic and Functional Diversity

Environmental Genomics and Related Methods

Culture-dependent sample processing

- Inoculum: the sample from which microorganisms will be isolated
- Make culture media which contained toluene
- serial dilutions performed to 10−7
- Using Selective Single Cell Isolation Microfluidics
- Choose the well where has lowest toluene concentration
- Using Gram stain & microscopy or 16S rRNA sequencing to check whether we have a pure culture.
- If we can get pure culture, can assume there is a toluene degrader existed

Culture-independent sample processing

- Inoculum: the sample from which microorganisms will be isolated
- Make culture media which contained toluene
- serial dilutions performed to 10−7
- Enrichment culture and total sample DNA isolation
- Using or General Staining Methods or Fluorescence In Situ Hybridization (FISH)

b. I think Culture-independent should be more reasonable. For General Staining Methods, it Can be used to track live bacteria and bacterial processes and act as a reporter, which is helpful for finding degrader. On the other hand, for Selective Single-Cell Isolation, it's more likely to fail to get pure culture condition.

3.

"specific growth rate" is also called Monod Kinetics, whose equation is $\mu = \frac{\mu_{max} \cdot S}{K_S + S}[time^{-1}]$,where μ_{max} is the maximum specific growth rate, K_S is the Monod half saturation constant (g/L), and *S* is the concentration of the limiting substrate (g/L). These two coefficients will differ between species and based on the ambient environmental conditions.

"generation time" is when one cell eventually separates to from two cells and the time required for this precess. It is dependent on growth medium and incubation conditions. On the other hand, the growth curve of microbial culture describes the entire growth cycle and is made up if four phases: lag, exponential, stationary and death, during the exponential period, generation time can be described as $g = t/n$, and generation time decrease during this period.

4.

Cyanobacteria: The prominent marker in the geological record, Fe^{3+} oxide minerals, shows the metabolism of cyanobacteria can yielded oxygen by oxidizing minerals from Fe^{2+} to Fe^{3+}. The presence of Cyanobacteria can produce oxygen which convert Earth environment from anoxic to oxic.

Oxygen:Molecular and chemical evidence indicates that levels of O_2 was low as now in the atmosphere. By 2.4 billion years ago, oxygen levels had risen due to the metabolism of cyanobacteria yielded oxygen that oxidized reduced minerals containing Fe^{2+} to Fe^{3+}. As oxygen accumulated on Earth, the atmosphere gradually changed from anoxic to oxic. Then it created conditions for the evolution of various new eukaryotic, which can evolved the capacity to respire O_2 gained a tremendous energetic advantage because of the high reduction potential of the O_2/H_2O couple. Thus, there are more aerobes could reproduce far more rapidly than anaerobes.

Ozone: when oxygen is subject to UV radiation from the sun, it is converted to ozone, which strongly absorbs UV radiation in wavelengths up to 300nm. As we known, UV irradiation from the sum would have made Earth's surface fairly inhospitable for life, then these ozone formed from oxygen develop an ozone shield, eukaryotic cells could range over the terrestrial surface of Earth.

5.

a. According to the contact time equation

$C = \frac{C_t}{t_{10}}$ then for Original procedure: $C_t = C \times t_{10} = 0.5mg/L \times 120min = 60mg{\cdot}min/L$

for New procedure: $C_t = C \times t_{10} = 2.5mg/L \times 32min = 80mg{\cdot}min/L$

b.EPA Surface Water Treatment Rule states at least: 99.9% (3-log) removal of giardia and 99.99% (4-log) removal of enteric viruses.

Then according to the table 1, Giardia removal is 3-log and virus is 4-log by filtration leaving 0.5 log inactivation for Giardia and 2-logs for viral disinfection.

Ct required for = 0.5 log inactivation for Giardia & 2-logs for viral = 100 mg/L min

Then

For original procedure:

$$C = \frac{C_t}{t_{10}} = \frac{100mg{\cdot}min/L}{120min} = 0.833mg/L > 0.5mg/L(Original\ procedure)$$

For New procedure: $C = \frac{C_t}{t_{10}} = \frac{100mg{\cdot}min/L}{32min} = 3.125mg/L > 2.5mg/L(Newprocedure)$

According to the result, neither of original procedure and new procedure can fulfills the EPA Surface Water Treatment Rule.

There are still other efficient disinfections, such as ozone, chlorine, chloramine, UV, or combinations used as final step to remove pathogens. These efficient disinfections combined not only can improve efficiency but also make water treatment more eco-friendly.