

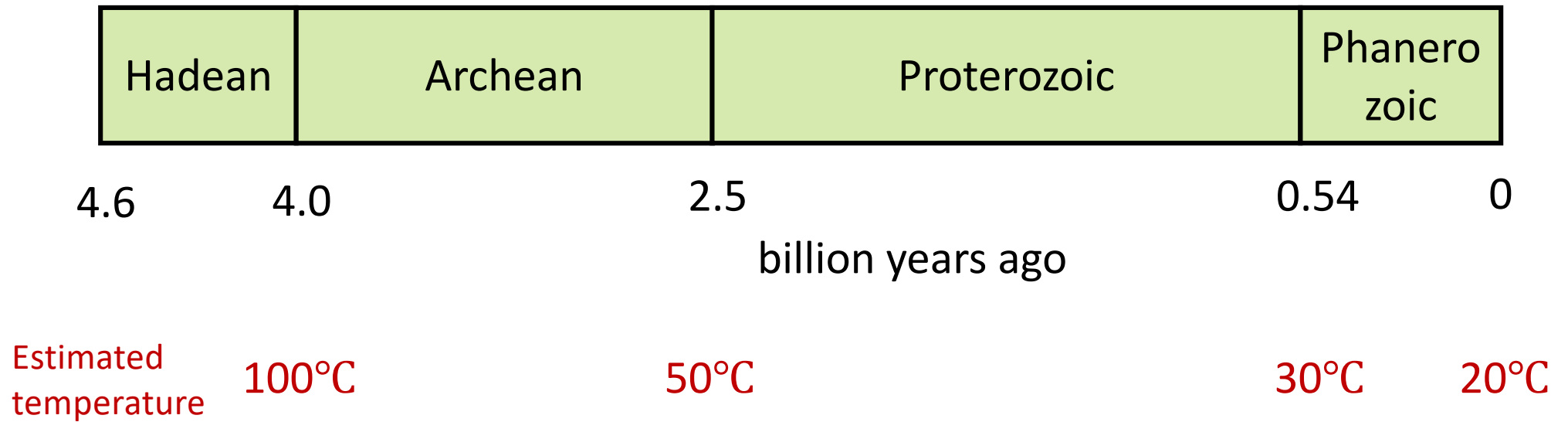


Changes in energy metabolism of microbes along with temperature drop in Nakabusa hot springs and relationship with Archean evolution of life

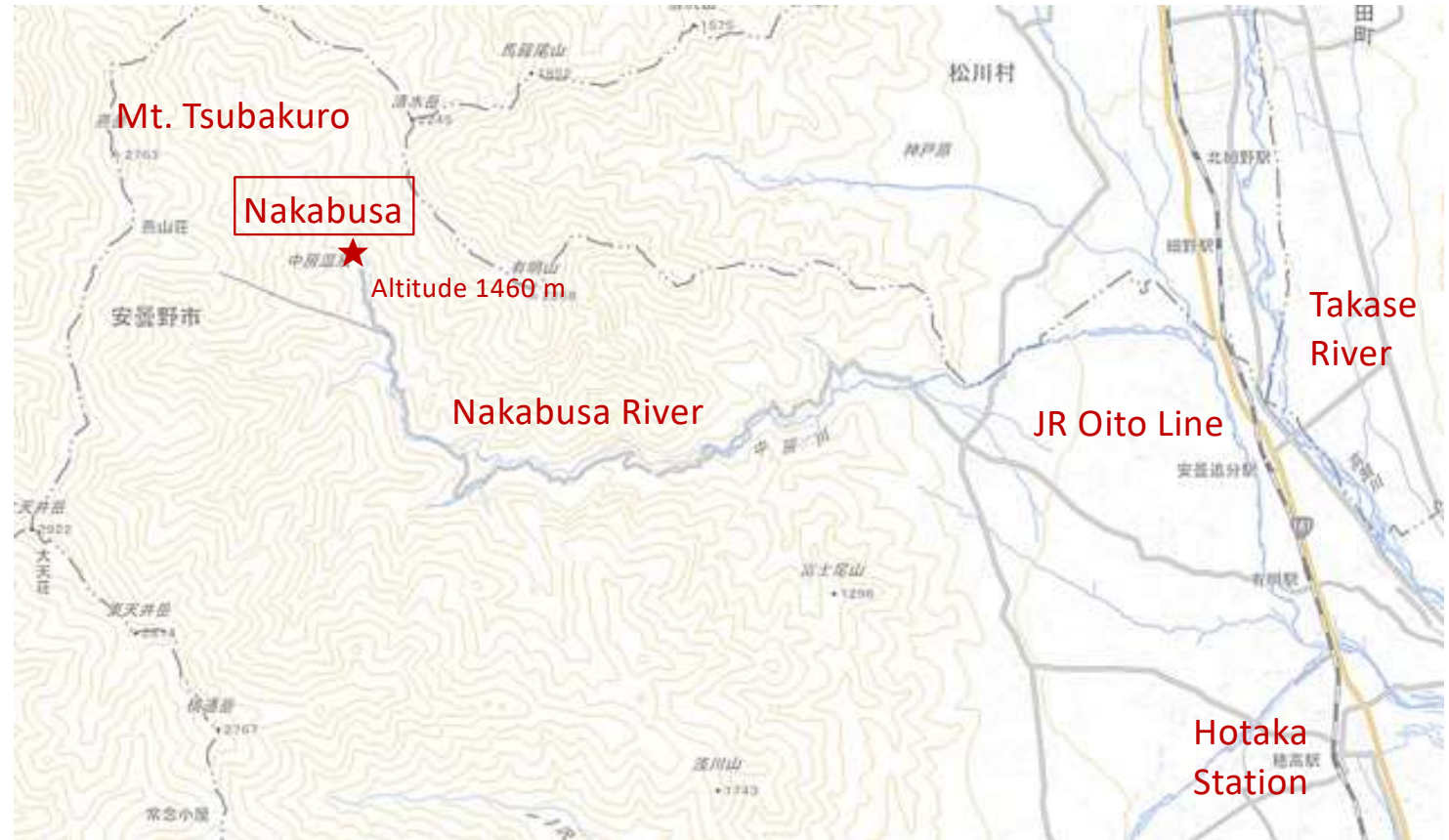
Katsumi Matsuura^{1, 2}, Shigeru Kawai³, Shawn E. McGlynn²

¹ Inst. Early Metabolic Evolution, ² ELSI, Tokyo Tech., ³ JAMSTEC

Geologic ages and estimated surface temperature



Nakabusa Hot Springs in Nagano: Sulfur spring: hydrogen sulfide type, alkaline



More than 30 springs
Temperature 60°C~95°C
Outflow 1500 L/min

pH 8.0~9.5
Sulfide 200~400 μmol/L
Sulfate 150~300 μmol/L
Carbonate 1.5~2.5 mmol/L

Chemosynthetic and photosynthetic microbial communities at Nakabusa

Kassen spring : 87°C at source : horizontal flow



86°C



66°C



56°C

Kojiki spring : 80°C at source : vertical flow



78°C



63°C

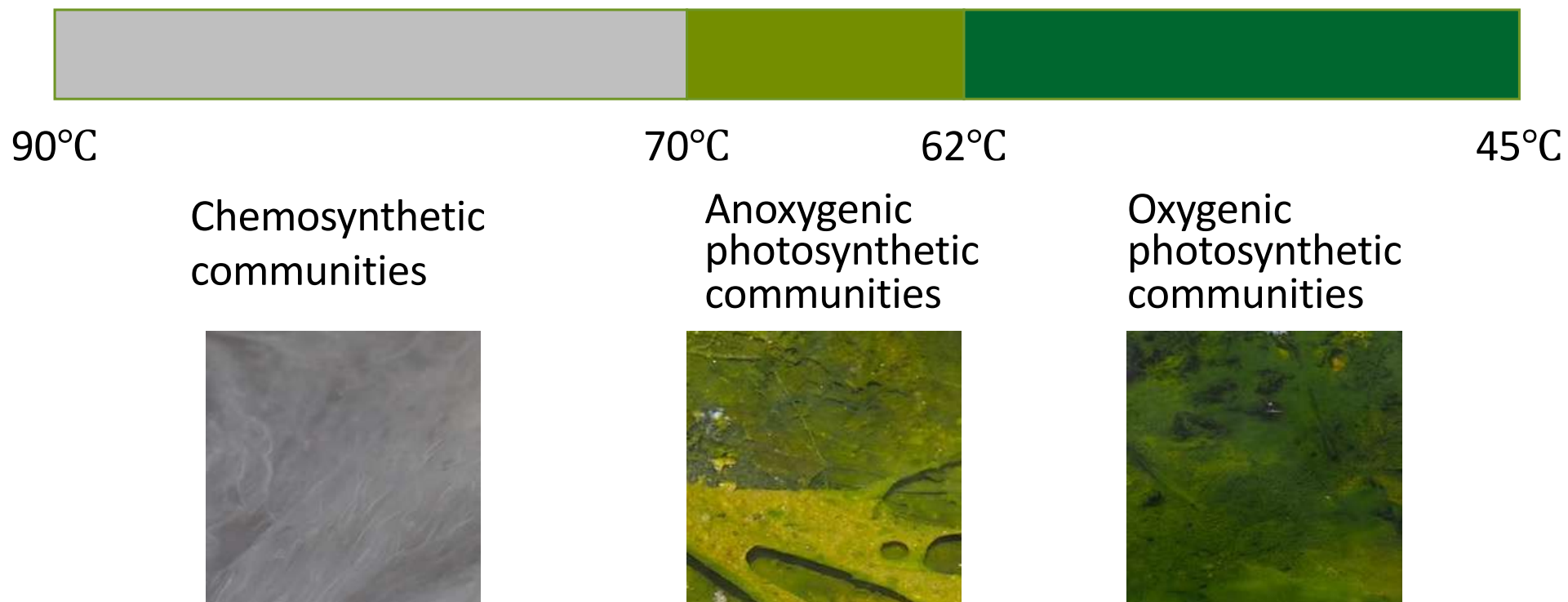


58°C

High-temperature zones and microbial communities in Nakabusa hot springs

Temp.: 45°C - 90°C Flow rate: 0.1 – 1200 mm/s Sulfide: 0 – 300 $\mu\text{mol/L}$ Oxygen: 10 - 180 $\mu\text{mol/L}$

Estimate from color (absorption spectrum) and non-inclusive genetic analysis



Methods

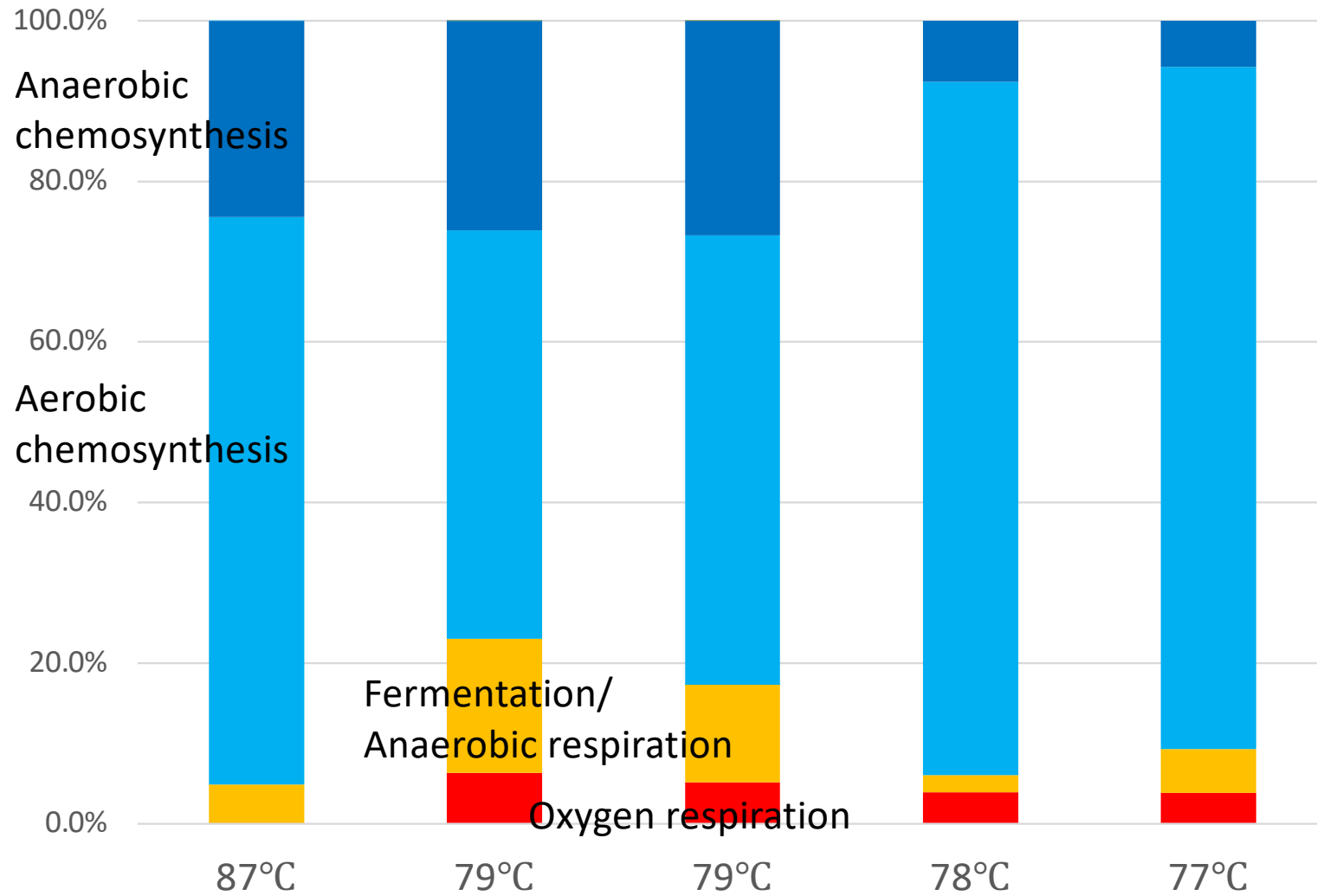
1. Each 0.2 g of the microbial mat sample was collected.
2. Temperature, pH, redox potential, oxygen concentration, hydrogen sulfide concentration, and flow rate were measured.
3. PCR amplified a portion of the ribosomal gene from each sample, and approximately 40,000 DNA sequences were determined.
4. The obtained sequences were classified into species levels, and the number of reads of each species was obtained.
5. The energy source* for each species was estimated, and graphs of the percentage of the energy source were depicted.

* Anaerobic chemosynthesis, aerobic chemosynthesis, anoxygenic photosynthesis, oxygenic photosynthesis, fermentation/anaerobic respiration, oxygen respiration

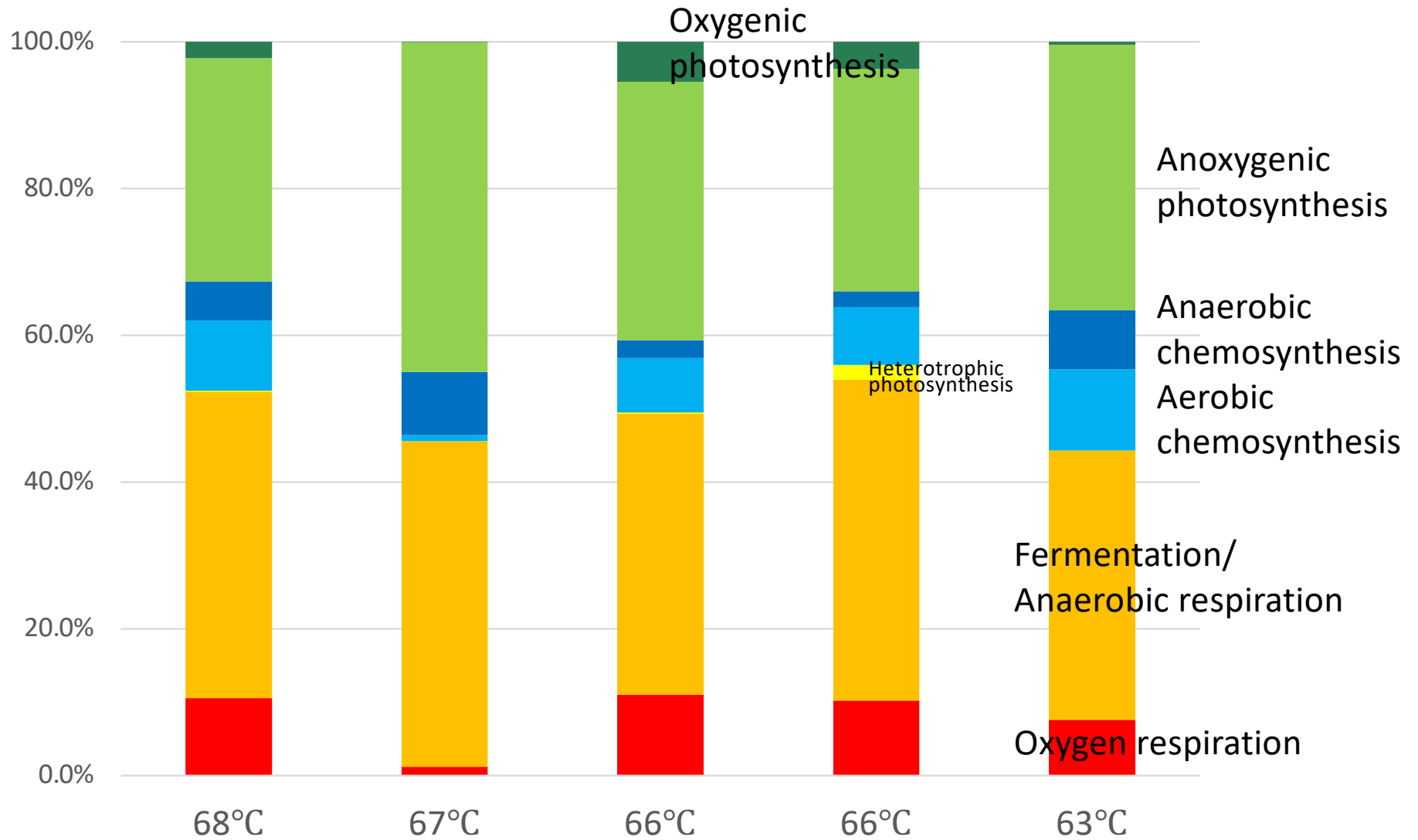
Diverse microbes in metabolism: Carbon Sources and Energy Sources

Carbon source	Energy source	Without oxygen (anaerobic)	With oxygen (aerobic)
CO ₂	Oxidation reduction of inorganic matter	Anaerobic chemosynthesis	Aerobic chemosynthesis
	Light	Anoxygenic photosynthesis	Oxygenic photosynthesis
Organic compounds	Oxidation of organic comp.	Fermentation/ anerobic respiration	Oxygen respiration

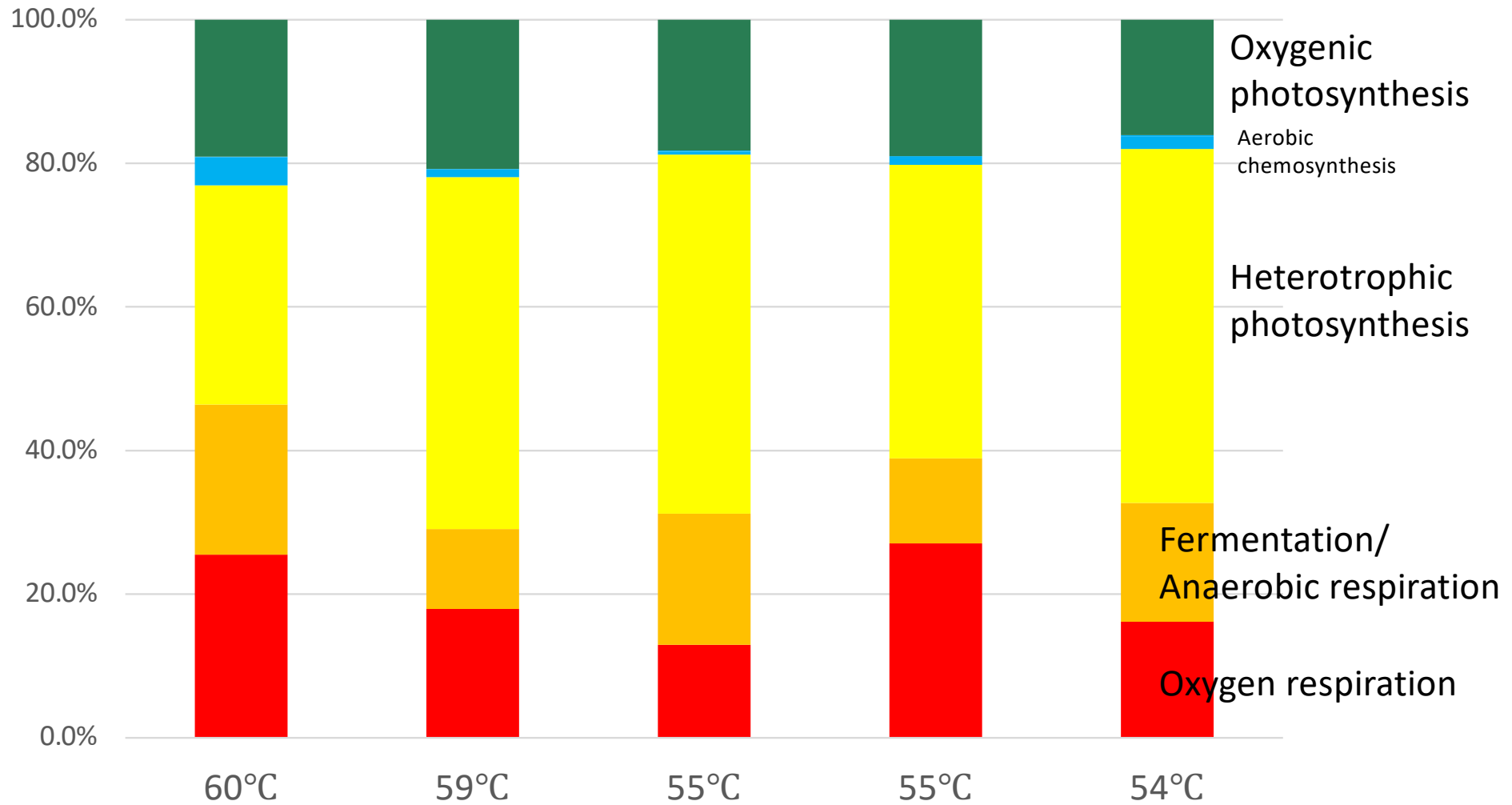
Proportion of microbes in energy metabolism in chemosynthetic communities



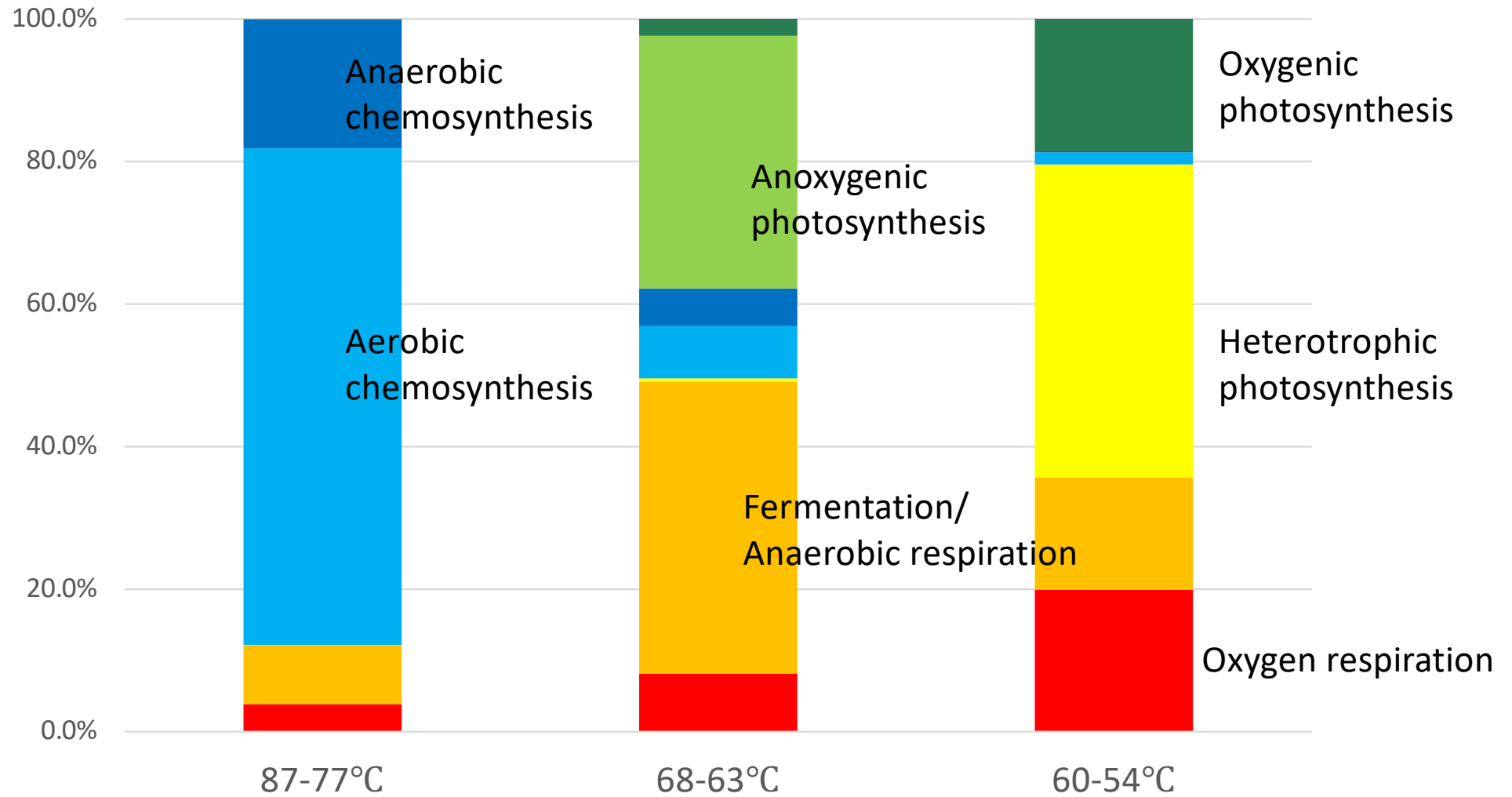
Proportion of microbes in anoxygenic photosynthetic communities



Proportion of microbes in oxygenic photosynthetic communities



Changes in microbial energy metabolism associated with temperature drop



Summary

Changes in microbial communities along the temperature decrease in Nakabusa hot springs indicate that

1. the order is chemosynthesis, anoxygenic photosynthesis, and oxygenic photosynthesis.
2. there is a possibility resembling the process of evolution in Archean.
3. It seems significant to investigate the evolution in detail there.
4. the place helps educate about the early evolution of life since the crucial microbes can be seen easily.

