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Differential Phototactic Behavior of Closely Related Cyanobacterial Isolates from Yellowstone Hot Spring Biofilms

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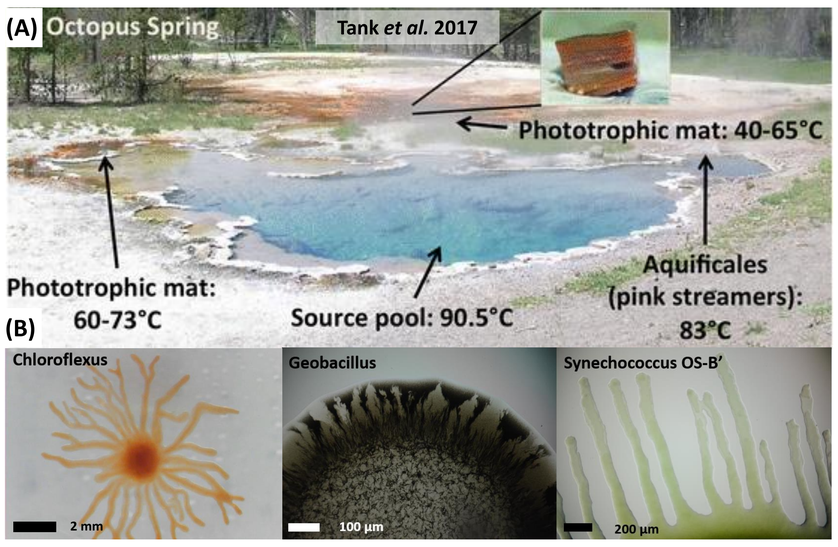
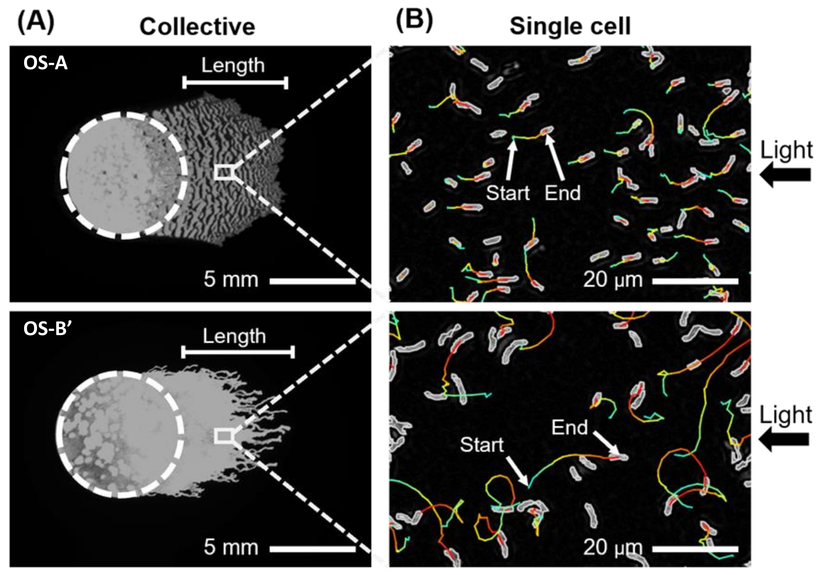


- Hot springs such as Octopus spring (shown above) in Yellowstone NP support thermophilic biofilm communities.
- Diverse phototrophic and heterotrophic bacteria can be isolated from the mat and many exhibit motility.

Introduction

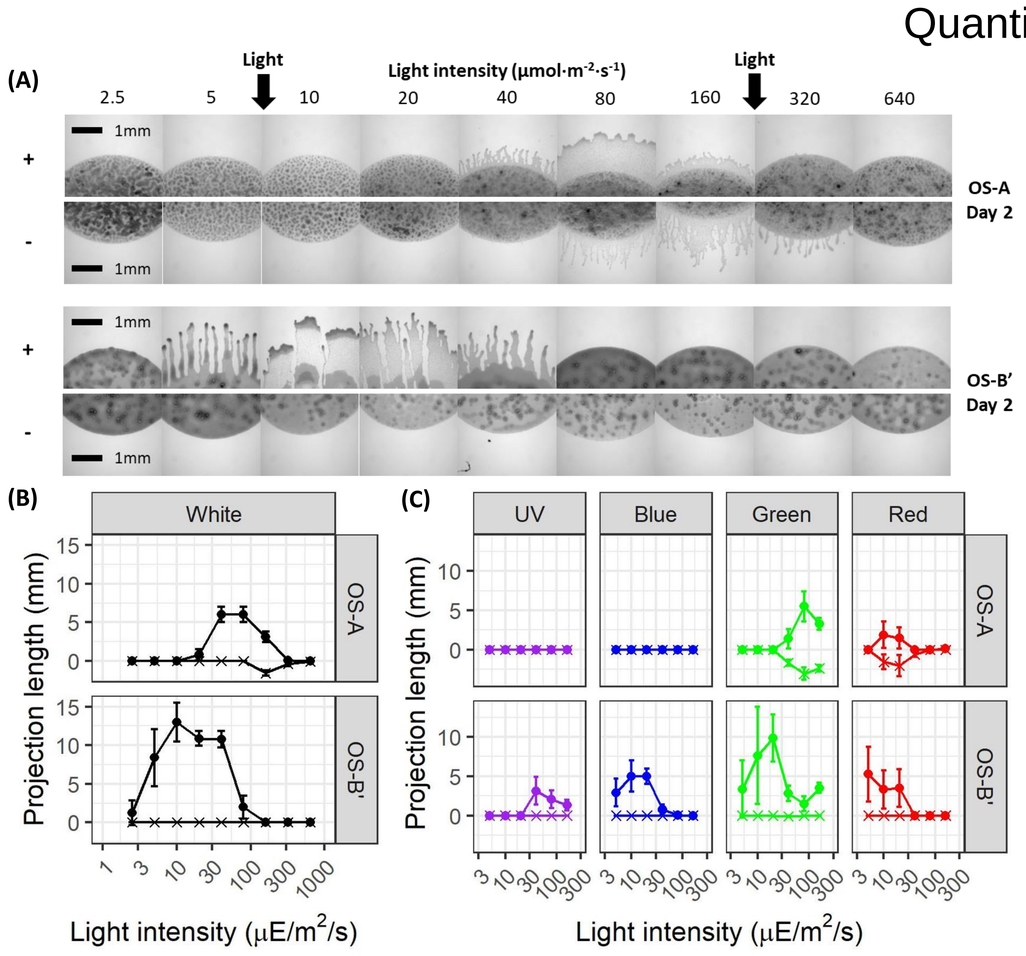
Cyanobacteria are keystone species in hot spring biofilms and show varied phototactic responses to the light environment.

- Yellowstone National park hot spring outflows are lined with dense and layered **microbial biofilms**.
- **Synechococcus** is the keystone species at 50-70˚C providing fixed carbon and nitrogen to the community.
- There are two dominant Synechococcus species: **OS-A** dominates at 60-65˚C and **OS-B'** at 50-55˚C.
- OS-A and OS-B' are also found at **different depths** in the biofilm and this changes over the diel cycle.
- We quantified the light dependent **motility** of OS-A and OS-B' at the **single cell** and **collective** level.
- We found differences between their **phototaxis** phenotypes and their **photoreceptor** sequences.
- Cyanobacteria have diverse photoreceptors and phototactic phenotypes suggesting **phototaxis is finely tuned** to the local light environment.

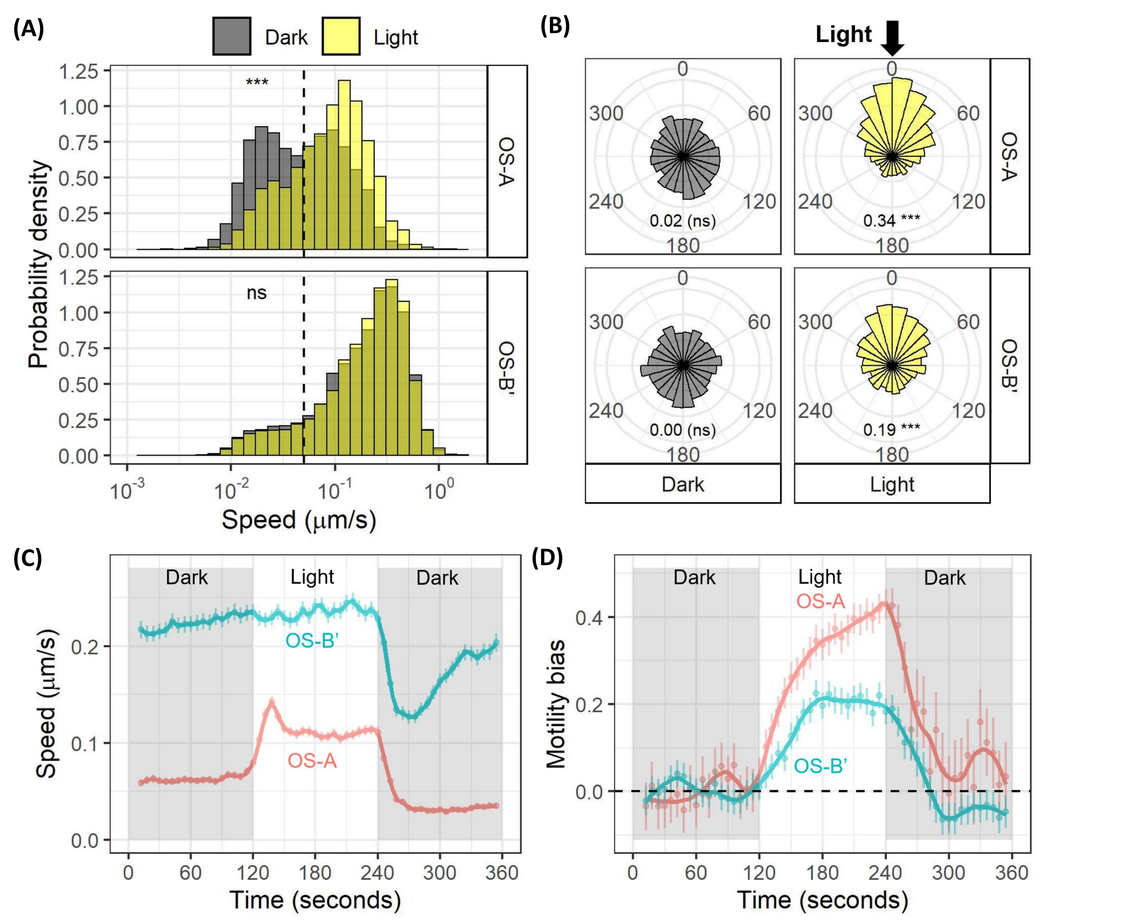


- OS-A and OS-B' mostly move collectively in groups but can also move as single cells.
- Particle tracking software allows us to quantify and analyze their dynamic responses to light.

Quantifying phototaxis

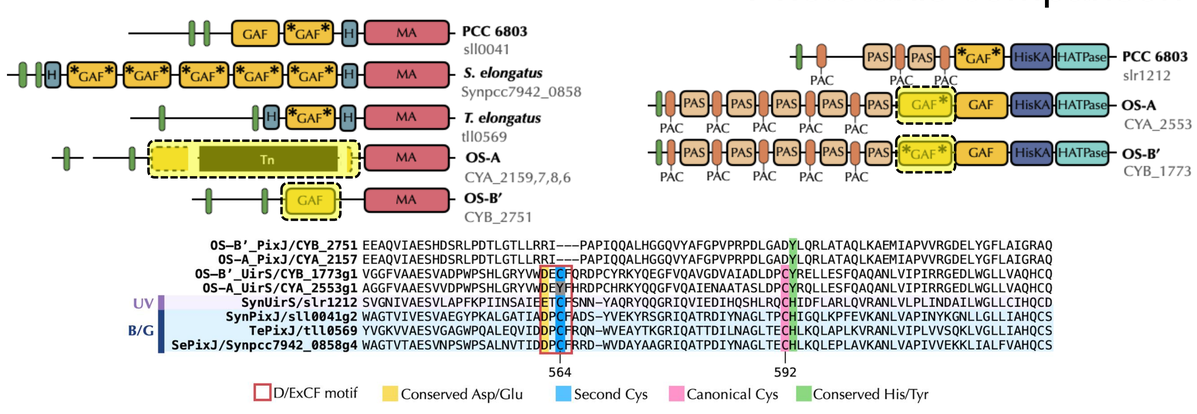


- OS-A performs more phototaxis at a higher light intensity than OS-B'.
- OS-A exhibits negative phototaxis but OS-B' does not.
- OS-B' responds to UV and blue light, but OS-A does not.



- OS-B' moves faster than OS-A.
- From dark to light, OS-A increases speed while OS-B' does not.
- OS-A has a larger phototactic bias than OS-B'.

Phototaxis comparison with other cyanobacteria



- OS-A and OS-B' appear to lack a functional PixJ homolog.
- OS-B' has both bilin binding cysteines in the UirS homolog and OS-A only has one.

Isolate/Species	Environment	Photo-kinesis	Positive phototaxis (bias value)	Negative phototaxis	Opt intensity (µmol·m^{-2}·s^{-1})	Phototaxis photoreceptors
Synechococcus OS-A	Hot spring	Yes	Yes (0.3)	Yes	40-80	UirS
Synechococcus OS-B'	Hot spring	No	Yes (0.2)	Yes (transient)	10-20	UirS
Synechococcus C1	Hot spring	Yes	Yes (nd)	Yes	nd	nd
Synechococcus C9	Hot spring	Yes	Yes (nd)	Yes	nd	nd
T. elongatus BP1	Hot spring	No	Yes (nd)	No	25-100	PixJ, PixD
T. vulcanus NIES-2134	Hot spring	nd	Yes (nd)	Yes	70	PixD
S. elongatus UTEX 3055	Stream	nd	Yes (0.35)	Yes	20	PixJ
Synechocystis PCC 6803	Freshwater lake	Yes	Yes (0.5)	Yes	1-10	PixD, PixJ, UirS

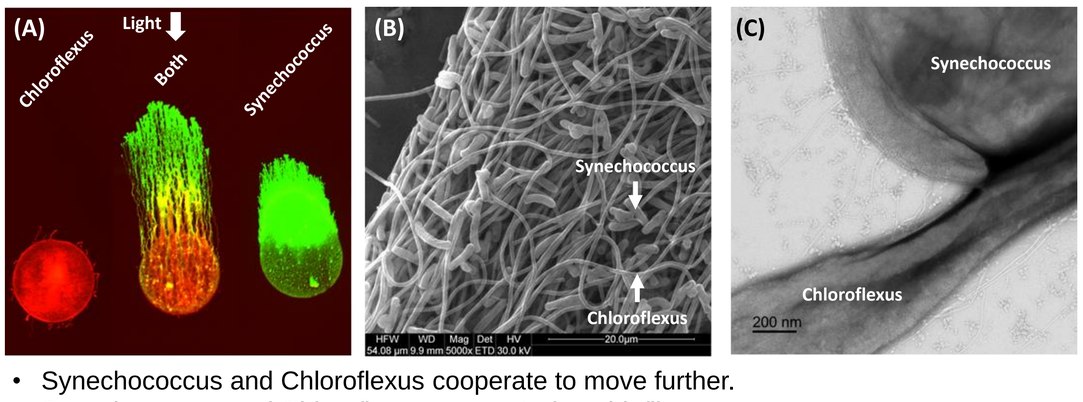
- Phototactic cyanobacteria encode only some homologs of Synechocystis photoreceptors.
- Cyanobacteria show +ve and –ve phototaxis over a range of light intensities.

Conclusions

- Synechococcus alters its motility in response to light quality, intensity and duration.
- OS-B' is faster, less phototactically biased, and more sensitive to low intensities than OS-A.
- Diverse cyanobacterial phototactic phenotypes and genotypes reflect different phototactic strategies.

Future work

- Characterize the motility of other thermophilic bacteria from hot springs.
- Investigate the role of motility and physical interaction in building biofilm architecture.
- Determine the role of biofilm structure in facilitating species growth and nutrient exchange.



- Synechococcus and Chloroflexus cooperate to move further.
- Synechococcus and Chloroflexus appear to form biofilms.
- Synechococcus and Chloroflexus appear to attach to one another.

Acknowledgements

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