AuPS/ASB Meeting - Canberra 2005

Free Communications 8: Biophysics

Thursday 29 September 2005

Chair: Paul Smith

Bicarbonate is not a physiological substrate of Photosystem II

I.L. McConnell, W. Hillier and T. Wydrzynski, Photobioenergetics Group, The Research School of Biological Sciences, The Australian National University, Canberra, ACT 0200, Australia.

Photosystem II (PSII) produces essentially all the molecular oxygen (O_2) in the atmosphere. The photochemistry of this large transmembrane protein complex has radically changed the planet since its evolutionary origin over 2.5 billion years ago. PSII catalyses a light dependent charge separation to drive electron transfer from water to plastoquinone and, as a by product of the reaction, oxidizes water, which releases O_2. The oxidation chemistry proceeds *via* a catalytic component called the oxygen evolving complex (OEC). The OEC consists of a bio-inorganic core containing four manganese ions joined by oxo bridges, and a calcium ion ($Mn_4O_xCa_1$). Additionally, it is coordinated to a number of surrounding amino acids from the supporting protein matrix. The mechanism of oxygen formation is subject to considerable speculation.

During the last several decades there has been simmering debate over the precise nature of the immediate substrate of the OEC. It is widely accepted that water is the ultimate substrate based on labeling studies with $H_2{}^{18}O$. However bicarbonate has been considered as an alternative intermediate and this has never been fully discounted. The interest in HCO_3^- has recently been rekindled by the inclusion of a (bi)carbonate ligand in the OEC in a crystal structure of PSII at 3.5 Å resolution (Ferreira *et al*., 2004).

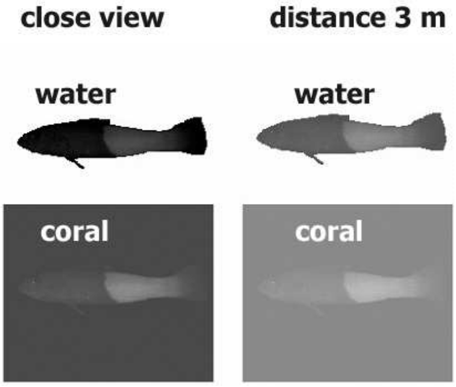
Using ^{18}O labeled bicarbonate in conjunction with membrane inlet mass spectroscopy the substrate flux into O_2 has been measured in three species of photosynthetic organisms, including a cyanobacterial species requiring high bicarbonate (400 mM) to grow. Evidence is presented that bicarbonate is not the physiological substrate of the OEC. Bicarbonate can only be oxidized by one in a few thousand PSII.

Ferreira, K.N., Iverson, T.M., Maghlaoui, K., Barber, J. & Iwata, S. (2004) *Science* **303**, 1831–1838.in 0

Spectra of reef fish – a physics approach to colourful patterns

Misha Vorobyev and Justin Marshall, Vision Touch and Hearing Research Centre, School of Biomedical Sciences, University of Queensland, QLD 4072, Australia.

Coral reef fishes use brightly coloured body patterns for advertisement and camouflage. How are these conflicting demands combined? Simple inspection of colourful patterns of reef fish provides little insight into this problem, because fish vision differs substantially from ours. To investigate the utility of fish colours, we calculated the number of quanta absorbed by cone photoreceptors (cone quantum catches) in fish eyes viewing fish. These calculations were based on measurements of reflectance spectra of fish skin, spectra of light under water and spectral sensitivity of fish cone photoreceptors (Losey *et al.*, 2003; Marshall *et al.*, 2003). Cone quantum catches provide full description of colour, because surfaces that differ in their reflectance spectra, but yield similar quantum catch in photoreceptors, cannot be discriminated. To reconstruct views of a fish as seen through fish eyes, we encoded each point of a fish image with the set of quantum catches that were calculated for the reflectance spectrum in a corresponding point (Vorobyev *et al.*, 2001; Marshall & Vorobyev, 2003). This method allowed us to visualise the information available to fish brain, but it does not take into account the neural processing of photoreceptor signals.



The Figure shows a royal dottyback, *Pseudochromys paccagnellae*, as seen by an achromatic colour channel of a barracuda. We placed this fish against the background of water (upper panel) and of coral (lower panel). The head of this fish provides little contrast with coral, while the highly contrasting tail may serve as a signal. This fish usually hides its tail in the burrow and exposes its head. Many reef fishes are sensitive in the UV part of the spectrum, but none of them have photoreceptors that are sensitive to orange and red. Therefore, bright for our eyes red and orange colours of many reef fishes may look dull for fish. Often patches of skin that look red for us reflect in the UV-blue part of the spectrum; these reflectances yield signals in UV or blue sensitive photoreceptors in fish eye, and may strongly contrast with yellow patches that usually absorb in the UV-blue part of the spectrum. Since the illumination spectrum varies significantly under water, fish colours also change. Another important physical factor that affects colour appearance is spectrally selective absorption and scatter of light by water. One of the consequences of light scatter is a veiling effect, which reduces contrast (the Figure, right column). Since scatter is most prominent in the UV part of the spectrum, UV reflectance cannot be transmitted at long distance. Many small fishes probably use UV as a ‘secret communication channel’ that conveys signals visible at close distance, but is invisible for predators from long distance. Another trick, used by colourful fish to avoid being seen from far distance, is to combine strongly contrasting blue and yellow colours whose optical mixture is similar to the spectrum of background (Marshall & Vorobyev, 2003). Due to the scatter of light in water and the poor optical resolution of fish eyes, the body pattern of such fish cannot be resolved when viewed from a distance. Therefore a colourful fish appears to be well camouflaged.

Losey, G.W., McFarland, W.N., Loew E.R., Zamzow J. & Marshall, N.J (2003) *Copeia* **3**, 433-454.

Marshall N.J., Jennings K.J., Losey, G.W. & McFarland, W.N. (2003) *Copeia* **3**, 455-466.

Marshall, N.J. & Vorobyev, M. (2003) In: *Sensory Processing in Aquatic Environments.* Ed. S.P. Collin & N.J.Marshall, Springer, pp 194-223.

Vorobyev, M., Marshall, J., Osorio, D., Hempel de Ibarra, N. & Menzel, R. (2001) *Color Research and Application* **26**, S214-216.

Resonances of the human vocal tract and some of their uses

John Smith and Joe Wolfe , School of Physics, University of New South Wales, NSW 2052, Australia.

The human vocal tract behaves approximately as an acoustical waveguide with a series of resonances whose frequencies may be varied by adjusting the position of tongue, lips and teeth. In voiced speech, these resonances interact with the harmonics of the lower frequency signal from the vibrating vocal folds to produce associated peaks, or formants, in the output spectrum. Such formants are characteristic of vowels in speech.

Singers sometimes use these resonances in musical rather than linguistic ways. For sopranos, the vibration frequency of their vocal folds may be much higher than the normal values for the lowest resonance, and consequently a reduced interaction would cause a loss of power. Direct measurements of the resonance frequencies of the vocal tract of classically-trained sopranos during singing show that they consistently increase them to match the frequency of their singing. This significantly increases the loudness and the uniformity of tone, at the expense of comprehensibility. The fundamental frequency of other singers is usually less than the value of the lowest resonance and so they would experience no advantage in tuning this resonance. However the power could be increased if the resonance frequency were tuned to a harmonic of the fundamental frequency. Our measurements indeed show that some altos, tenors and baritones use this strategy when appropriate.

The role of the vocal tract resonances is quite different when playing a wind instrument. The sound is then generated by the vibrating lip or reed valve rather than by the vibrating vocal folds. The frequency of vibration is then primarily determined by one of the strong resonances of the wind instrument itself. Our measurements show that varying the resonances of the vocal tract can then still slightly alter the vibration frequency and change the harmonic structure or timbre of the produced sound.

The research described has involved several members and associates of our Acoustics Laboratory. http://www.phys.unsw.edu.au/speech http://www.phys.unsw.edu.au/music