



Synaptic Switch and Social Status

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DSCs are extremely good at separating photogenerated charge carriers and taking them to the electrodes. If an incoming photon is absorbed by the dye in a state-of-the-art DSC, the probability of the charge carriers reaching the electrodes is nearly 100%. Until recently, the world record for power conversion was 11.1% (4). Although the sensitizing molecules in these cells have a relatively large energy gap, the cells do not generate as high a voltage as one could reasonably expect because the redox potential of the most commonly used redox couple, which is based on iodide ions, is too low for the best sensitizing dyes (see the figure, panel B). Energy is wasted as the redox couple reduces a charged-sensitizing dye back to its neutral state.

Many researchers have been trying for more than a decade to find a redox couple with a more ideally suited redox potential in order to increase the voltage of DSCs, but the process has been slow and frustrating. The iodide mediator is special as its oxidized form, I_3^- , does not readily accept electrons from the titania surface, which would be an unwanted recombination process (5). The I_3^- ions can persist for 1 ms or more before undergoing an electron-transfer reaction in solution, which gives them sufficient time to diffuse to the counterelectrode for reduction. Several alternative metal complexes with better redox potentials have been found, but solar cells made with them typically have unacceptably high recombination rates and lower open-circuit voltages.

Last year, Boschloo, Hagfeldt, and co-workers achieved a power-conversion efficiency of 6.7% in DSCs with iodide-free electrolytes using Co complexes (6). The key to making good cells was adding just enough electrically inactive bulk to the periphery of the sensitizing dyes and the Co complexes to slow down recombination without blocking the necessary electron-transfer processes.

The approach Yella *et al.* took to slowing down recombination was to use a relatively new family of dyes that connect an electron donor (D) moiety to an electron acceptor moiety (A) through a conjugated (π -bonded) bridge (D- π -A) provided by a zinc porphyrin complex. These D- π -A dyes do not contain any expensive, rare metal atoms, such as Ru, and tend to absorb light more strongly. Most important, they attached alkoxy chains to the sides of these molecules to provide a very effective barrier to recombination between electrons in the titania and holes in the Co complexes.

One of the shortcomings of the Co complexes is that they diffuse through the elec-

trolyte more slowly than the conventional iodide ions because they are larger. Yella *et al.* found that they could get efficiency as high as 13.1% by reducing the illumination intensity by 50% because it is less important for the ions to diffuse to the electrode quickly when the carrier density is lower. This efficiency might be obtained under normal solar lighting by reducing the distance the ions need to diffuse through the use of thinner films. Complete absorption in these thinner films could be achieved by using even better D- π -A dyes that absorb more strongly or advanced light-trapping techniques such as plasmonics (7, 8). Long-term stability studies must be performed on Co complexes in dye-sensitized solar cells to determine if they are as stable as iodide-based electrolytes.

For many years, dozens of researchers around the world tried to develop new sensitizing dyes and redox couples for DSCs but inevitably concluded that the best sensitizing dyes needed to contain Ru and the best mediators needed to contain iodide. These paradigms are now shattered. One of the next developments that needs to occur is

reducing the energy gap of sensitizing dyes so that light can be harvested efficiently further into the infrared region of the spectrum. One approach would be to use sensitizing dyes to absorb infrared light and energy relay dyes that absorb visible light, and then transfer energy to the sensitizing dyes (9). As scientists around the world develop new D- π -A dyes and redox couples and combine them with energy relay dyes and new light-trapping techniques, we can expect to see the efficiency climb toward 15%, which could make DSC technology competitive with other kinds of solar cells.

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NEUROSCIENCE

Synaptic Switch and Social Status

Matthieu Maroteaux and Manuel Mameli

The strength of synaptic connections in the mammalian brain can influence social status.

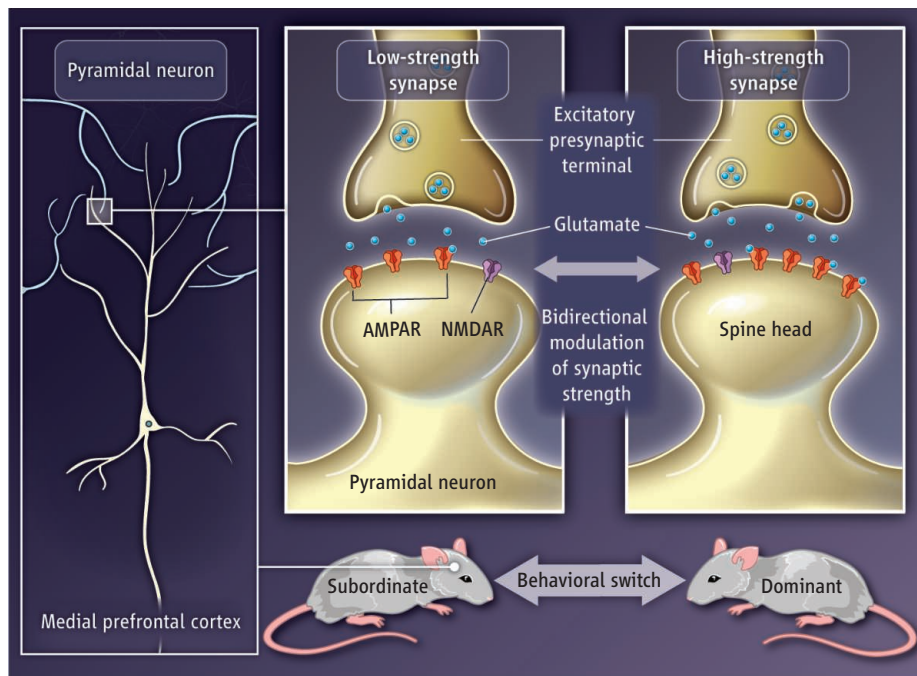
In 1859, Charles Darwin introduced the key concept of natural selection—that in the struggle for survival and reproduction, individuals compete for the same resources. Hence, animals living in a social environment can establish dominance hierarchies within a short time, which remain stable during the existence of the group (1). This ranking within social communities has a fundamental advantage—it eliminates conflict in the group, which minimizes energy expenditure and violence, thereby allowing resource sharing (2). On page 693 of this issue, Wang *et al.* (3) demonstrate that encoding of social dominance in mice involves specific synapses in cortical regions of the brain.

Wang *et al.* used a behavioral experimental model (4) that provides a quantitative

measure of aggressiveness without allowing physical contact between competing mice, thereby preventing injuries. In each trial, one mouse forces its opponent outside of a neutral area, permitting identification of a dominant and a subordinate mouse. The authors show that in a cohort of four mice, a social hierarchy was quickly organized and once established, persisted over time. Another important aspect is the complete independence of social dominance from other factors, including sensorimotor and learning skills. This makes hierarchy formation a unique and distinct trait of animal behavior.

When and where does nature decide that an individual will dominate in a community? Early in life, mice as well as humans are embedded in a community that in the simplest scenario consists of siblings. An interesting possibility is that innate traits and genetic programming that shape neuronal circuits from the postnatal period are responsible for the allocation of dominance or subor-

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Synapses and rank. Excitatory synaptic drive onto cortical pyramidal neurons in the mouse brain is stronger in dominant individuals than subordinates. Modulating synaptic strength by increasing or decreasing AMPA receptor-mediated transmission switches the initial social ranking.

dination. But in the case of newly established cohorts, where animals meet randomly, how does social dominance adjust? In one plausible sequence of events, a dominant individual suddenly facing subordination experiences a range of emotions, including disappointment or even fear. Stress has been proposed to affect social relationships in this context (5). Indeed, by acting both on neuronal circuits implicated in cognition and emotions and on hormone levels, stress amplifies memories associated with the previously established social status (6).

Changes in the synaptic strength of excitatory connections in the rodent hippocampus, amygdala, and midbrain represent a cellular substrate of experience-driven behaviors (7). This suggests the engagement of similar mechanisms during the encoding of social dominance. In humans, the dorsolateral prefrontal cortex (PFC), the homolog of the rodent medial PFC (mPFC), has been implicated in hierarchy-related behaviors. Wang *et al.* focused on excitatory synapses onto layer V pyramidal neurons of the mPFC (the main output of this structure) and show that the strength of synaptic transmission mediated by the neurotransmitter glutamate matches social ranking in mice (see the figure).

The stochastic release of individual neurotransmitter vesicles (quanta) has been used to probe the basic function of synapses in the neuromuscular junction and central nervous system (8). Wang *et al.* observed

that the size of quantal release onto cortical neurons was higher in dominant than subordinate adult mice (rank 1 versus rank 4 among four mice). As an outcome, higher synaptic efficiency will potentially translate into a stronger output signal from the cortex to downstream brain structures. The authors also established a causal link between strength of excitatory synapses and social dominance. Decreasing the synaptic transmission mediated by AMPA receptors (which are postsynaptically activated by the release of glutamate) switched the initial ranking—the dominant mouse became the subordinate member of the cohort (from rank 1 to rank 4). Likewise, an increase in AMPA receptor-mediated synaptic transmission switched the subordinate mouse to a dominant rank (rank 4 to rank 1). Thus, synaptic efficacy, specifically in cortical layer V, is sufficient to tune social status. Although the amount of AMPA receptors at synapses is unlikely to be the only mechanism that discriminates a dominant versus a subordinate mouse, these findings provide a further argument that manipulation of the synaptic strength by controlling the number or the trafficking of postsynaptic AMPA receptors directly modifies specific behaviors.

Wang *et al.* provide two conceptual advances: the idea that a neurobiological substrate for social ranking is located in the mPFC, and that synaptic efficacy represents a cellular substrate determining social sta-

tus. Although the mPFC has an established role in social behavior, it cannot be considered the only structure where dominance is encoded. Indeed, the amygdala and lateral septum are key players in establishing animal hierarchy (9). Future studies will be necessary to determine the hierarchical organization among brain structures underlying this complex behavior.

An interesting aspect arising from the study of Wang *et al.* concerns the mechanisms that establish glutamatergic transmission upon the first encounter of a stranger. It is plausible that mice might be differently programmed for leadership from birth. However, it cannot be ruled out that animals may also acquire their social status based on biological factors and external cues, thereby learning to be dominant or subordinate. If that is the case, this process might share traits with experience-driven behavior, where synaptic adaptations are crucial. How does the synaptic strength adapt in conditions where dominance is challenged? A network activity might be in part responsible for driving these processes or alternatively, synaptic scaling may take place more slowly over time (10, 11). Wang *et al.* demonstrate that impairing AMPA receptor trafficking to the synapse devalues the status of a dominant mouse. This raises the interesting possibility that AMPA receptors constitutively insert at synapses and maintain dominance over time.

Although Wang *et al.* demonstrate that social rank correlates with synaptic strength, they also highlight the need to further understand the differences between individuals at the cellular level. This could depend on the number of AMPA receptors, dendritic spines, or synaptic inputs—or a broader network tuning could be involved.

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