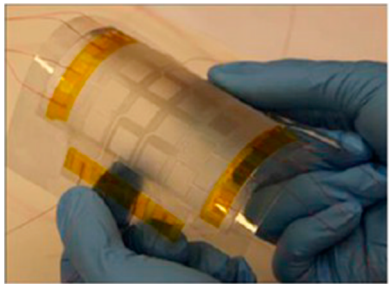
Tapping Human Touch for Biomechanical Energy

Finding ways to harvest biomechanical energy from human movement has attracted greater and greater attention. Thus far, researchers have developed several different techniques based on electromagnetic, electrostatic, and piezoelectric mechanisms. Recently, some groups have explored harnessing the triboelectric effect to scavenge mechanical energy, miniaturizing this technology into triboelectric nanogenerators (TENGs). These nanogenerators and all other biomechanical energy harvesting techniques have so far been based on attaching external devices to the human body.

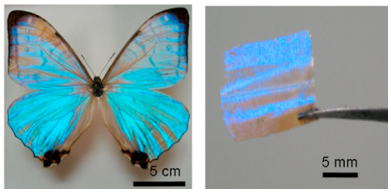
Flipping this paradigm around, Yang *et al.* (DOI: 10.1021/nn403838y) developed a TENG that generated a current based on touch. The researchers' system involves a polydimethylsiloxane (PDMS) film with a surface of micropyramid structures on an indium tin oxide (ITO) electrode. When this film is touched, the periodic change of distance between the PDMS and ITO results in a charge transfer between the electrode and the ground, driving a flow of electrons across an external load. This TENG generated an open-circuit voltage up to −1000 V, a short-circuit current density of 8 mA/m^2, and a power density of 500 mW/m^2 on a load of 100 mΩ. The researchers demonstrated its utility by attaching it to the back of a hand, showing that a single fast swing could light up tens of green LEDs. Placing it on a cell phone touchpad screen, touches generated an output power of about 0.2 mW. The researchers also show that the TENG can be used as a self-powered tactile sensor by using output voltage signals to generate a map. The authors suggest that this TENG could have potential applications in human–machine interfacing or touch pad technology.



Carbon Nanotube Networks Wing It

Human beings have long exploited natural materials, and as knowledge of their properties has grown, the list of potentially useful materials has grown. In particular, natural materials sourced from insects have offered many benefits that have improved quality of life and advanced science over the ages, including silk, honey, and luciferase. More recently, improved understanding of insect parts, including their wings, has made these materials interesting for various industrial applications. Insect wings have many unique and complex nanostructures and microstructures that researchers have yet to reproduce artificially. For example, the wings of *Morpho* butterflies have structural color, superhydrophobicity, self-cleaning properties, directional adhesive functions, and chemical-sensing capabilities.

Building on the list of this butterfly wing's useful properties, Miyako *et al.*

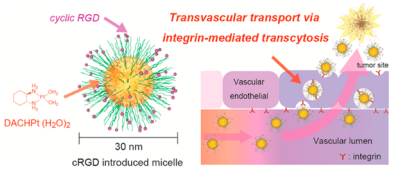


(DOI: 10.1021/nn403083v) combined *Morpho sulkowskyi* wings with carbon nanotubes. After drying dispersions of single-walled carbon nanotubes onto commercially available *Morpho* wings, the researchers found that the nanotubes formed honeycomb-shaped networks spread over the wings' scales. Building on the wings' natural capacity to collect solar energy efficiently and ability to trap light through refraction, the researchers found that combined nanotube–wing material increased significantly more under laser irradiation than either material alone or other similar carbon materials, such as multiwalled carbon nanotubes. This combination material also displayed high electrical conductivity. Additionally, the researchers were able to use the functionalized butterfly wings to amplify DNA using the photoinduced loop-mediated isothermal amplification method. The authors suggest that this novel material offers possibilities for a variety of future technologies, including applications in digital diagnosis, soft wearable electronic devices, photosensors, and photovoltaic cells.

Ligands Bust through Blood–Brain Tumor Barrier

Despite advances in treating many types of cancer, glioblastoma remains an intractable challenge. Researchers have not developed successful new treatment protocols that significantly extend patients' lives in decades. Because these tumors tend to metastasize readily, making complete surgical excision unlikely, radiation and chemotherapy play important roles in conventional glioblastoma treatments. However, chemotherapy success is typically limited as a result of poor drug penetration from blood vessels into tumors because of the blood–brain barrier and the blood–brain tumor barrier (BBTB). Although high doses of chemotherapy can circumvent the BBTB, side effects make this strategy untenable.

In a new study, Miura *et al.* (DOI: 10.1021/nn402662d) develop a novel strategy for getting drugs past the BBTB and directly to tumors by using targeting ligands placed on drug-carrying micelles. For targeting glioblastoma, the researchers used cyclic Arg-Gly-Asp (cRGD), which has a selective affinity for integrins that are overexpressed on the surface of glioblastoma cells and endothelial cells in tumor blood vessels. Loading micelles bearing different concentrations of this ligand with a platinum-based drug, the researchers compared these smart drug-delivery systems with micelles bearing a nontargeted peptide, cyclic Arg-Ala-Asp (cRAD). Results showed that micelles bearing high percentages of c-RGD were readily and quickly taken up by tumor cells, unlike those bearing c-RAD. In orthotopic mouse models of human glioblastoma tumors, intravital confocal laser scanning microscopy showed that the targeting micelles were able to bypass the tumor vasculature and invade the tumors, significantly inhibiting tumor growth, whereas the nontargeting micelles had no therapeutic effect. The authors suggest that this strategy could offer a promising new way to bypass the BBTB to treat glioblastoma.



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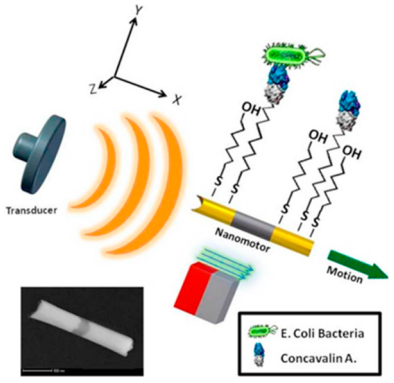
Nanomotors Wired for Biomedical Applications

Research toward creating nanomotors to power nanomachines has ramped up in recent years due to the diverse range of potential applications for this technology, ranging from nanoscale fabrication to biomedical uses. Thus far, synthetic nanomotors have been developed with a variety of different propulsion mechanisms. Although the majority of these have been chemically powered catalytic motors, this mechanism is largely incompatible with biomedical applications. Researchers have gotten around the need for fuel requirements by developing magnetically driven nanoswimmers and electrically propelled devices. Recently, ultrasound-driven propulsion has become a prospect for powering a new generation of fuel-free nanomotors.

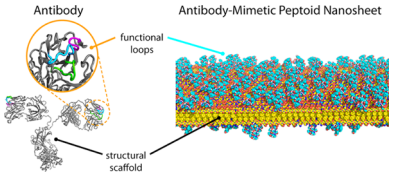
Toward this end, Garcia-Gradilla *et al.* (DOI: 10.1021/nn403851v) developed novel ultrasound-powered nanowire motors functionalized for a diverse variety of practical biomedical applications. The researchers used a template electrodeposition method to craft three-segmented nanowires with an Au/Ni/Au pattern. They deposited a copper sacrificial layer to create a concave cavity on one end of these nanomotors, which facilitated propulsion by ultrasound waves. The addition of the Ni segment provided magnetic alignment, allowing the nanomotors to be steered along predetermined trajectories. By modifying the Au surface with different self-assembled monolayers, the researchers were able to use the nanomotors to capture either *E. coli* or *S. aureus* selectively and specifically, and to maintain their viability. The researchers were able to modify their nanomotors further with a polypyrrole–polystyrene sulfonate segment to ferry chemical cargo, making them into drug-delivery vehicles. Tests showed that the nanomotors were able to operate in complex biological media, including unmodified serum and saliva. The authors suggest that these nanomotors show promise for diverse biomedical applications.



Building a Better Antibody Mimic

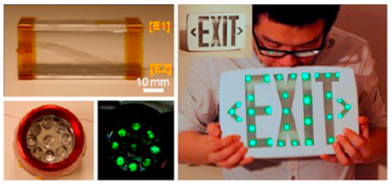
Researchers have long taken advantage of antibodies' natural ability to bind a large range of antigens to use these proteins for molecular recognition. However, the use of antibodies comes with significant drawbacks. Efficiently manufacturing and implementing antibodies in devices has technical challenges, including poor solubility, poor temperature and enzyme stability, and improper folding when expressed in bacteria. Combined with the need to engineer antibodies rapidly for novel targets, these limitations have prompted searches for alternatives that mimic natural antibody function but are more stable, cost-effective, and easier to manufacture.

In a new study, Olivier *et al.* (DOI: 10.1021/nn403899y) reveal an alternative to natural antibodies for molecular recognition: peptoid nanosheets functionalized with embedded peptide and peptoid loops that each serve as molecular recognition sites. To craft these novel antibody mimics, the researchers started with peptoid nanosheets that formed from amphiphilic peptoids coming together in a monolayer at the air–water interface, then laterally compressed them into a peptoid bilayer nanosheet. The researchers took advantage of this order of events to introduce short loops into the structure before it was compressed. This resulted in the short loops becoming enmeshed in the nanosheet structure without changing its native conformation. Numerous methods verified the presence of loops on the surface of the nanosheets, including atomic force microscopy and powder X-ray diffraction. The researchers confirmed the functionalized nanosheets' utility by using them not only as substrates for the enzymes protease and casein kinase II, but also as templates to grow Au films and nanocrystals. The authors suggest that these nanosheets could eventually be platforms for sensing and catalysis.



New Triboelectric Nanogenerator Makes Renewable Energy a Breeze

As "green" energy has become progressively important, wind energy has attracted increasing attention. Currently, most wind energy harvesters are based on electromagnetic and piezoelectric mechanisms. These devices have several drawbacks, including complex structures, large sizes, and significant mechanical wear over time. Consequently, researchers have sought novel ways to harvest wind energy, including triboelectric nanogenerators (TENGs), which scavenge mechanical energy from impact, sliding, and rotation. These TENGs could improve on current wind energy harvesting methods by simplifying device fabrication, lowering cost, and improving efficiency.

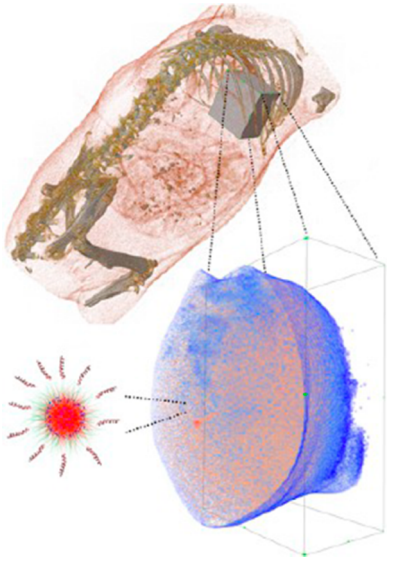


In a new study, Yang *et al.* (DOI: 10.1021/nn4043157) showcase a new type of TENG that can not only harvest wind energy, but also serve as the basis for a self-powered sensor for detecting wind speed and direction. Their device is based on periodic contact and separation between two Al foils and a fluorinated ethylene–propylene film, of which the surface area and roughness is enhanced with nanowire structures. Encasing these elements in a cuboid tube, the researchers tested their device using an air gun and later attached it to a car. They found that their TENGs connected in parallel delivered an output voltage up to 100 V, an output current of 1.6 A, and a corresponding output power of 0.16 mW under an external load of 100 M, enough to light up tens of LEDs. The researchers were able to use this system to detect wind direction and speed with a sensitivity of 0.09 A/(m/s). The authors suggest that these TENGs could eventually be used to sustain small electronics or as sensors for ambient wind detection.

Slipping in siRNA with Cell-Penetrating Peptides

Small interfering RNAs (siRNAs), short oligonucleotides that induce cellular mechanisms to cleave targeted mRNAs and thus inhibit translation of particular proteins, have the potential to treat a variety of diseases and disorders. However, progress for this family of therapeutics has been stymied by the lack of an effective way to deliver siRNAs into cells. One potential solution is attaching siRNAs to cell-penetrating peptides (CPPs), peptides that can facilitate entry into the cytoplasm. Many CPP sequences that have been examined as drug-delivery vehicles are derived from bacterial or viral proteins or are synthetic model peptides and, as such, are nonhuman proteins. These come with significant disadvantages, including the potential to trigger anti-CPP immune reactions. Developing humanized CPP sequences could alleviate this problem.

Toward this end, Karagiannis *et al.* (DOI: 10.1021/nn4027382) used a rational method to develop a library of CPPs that can

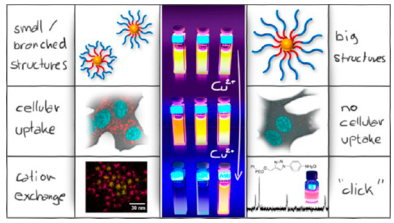


effectively get siRNAs into cells. The researchers used databases to locate human sequences from peptides that reside or interact with cellular plasma membranes. The researchers attached candidate sequences to lipid-like nanoparticles containing siRNAs and tested their ability to silence target genes in cells. They identified several sequences—including those for lactoferricin, surfactant protein B, and orexin—that effectively ferried siRNAs into cells and silenced genes *in vitro* at high efficiency. Testing this system *in vivo*, these three CPPs each facilitated siRNA entry into liver cells, resulting in significant knockdown of a liver-specific protein in animal models. The authors suggest that using a rational search could identify even more useful CPPs to bring siRNAs into cells.

Quantum Dots Go Undercover

Quantum dots' (QDs) extraordinary optical properties, including high extinction coefficients, broad absorption, narrow and adjustable emission, and high photostabilities, give them potential as useful labels for biological imaging. However, using QDs for biolabeling still faces some challenges. The ligand system for QDs must provide excellent shielding against biological media, which can include proteins, small organic molecules, and high concentrations of ions. These can greatly affect fluorescent properties as well as the stability of the ligand shell. The ligand system must also offer a site for bioconjugation reactions to take place. Although copper(I)-mediated "click" chemistry offers a useful way to couple biomolecules to nanoparticles, this coupling strategy tends to quench fluorescence.

Seeking a way to overcome these challenges, Ostermann *et al.* (DOI: 10.1021/nn4037859) used various diblock copolymers of different sizes and shapes to encapsulate QDs, providing shielding from biological media and allowing copper(I) catalyzed click reactions to take place without quenching. The researchers surrounded CdSe/CdS/ZnS QDs with poly(isoprene-*block*-ethylene oxide) (PI-*b*-PEO) diblock copolymers of different lengths or a miktoarm star polymer, allowing them to build constructs in a size range between 24 and 53 nm. Tests showed that the thicker coatings acted as better shields against ions, effectively preventing quenching while still allowing cellular uptake. Dense shells allowed the researchers to perform copper(I)-catalyzed click reactions while maintaining fluorescence. The authors suggest that diblock copolymers could provide a viable way to encapsulate and functionalize QDs for biological applications.



Catching Some Rays the Quasi-Epitaxial Way

Research suggests that in thin-film organic photovoltaic cells, the interface morphology affects the recombination rate for electrons and holes at donor–acceptor heterojunctions. The most optimal arrangement to maximize both the short-circuit current and open-circuit voltage seems to be disorder at the heterojunction but order in the bulk of the thin films. One way to achieve this goal is by using materials from the class of substances known as van der Waals solids, named after the weak bonds responsible for their intermolecular adhesion. When used in thin films, these materials result in a slight lattice mismatch between the film and substrate while still maintaining an ordered morphology. Not needing a precise lattice match leads to a so-called quasi-epitaxial growth.

Taking advantage of this phenomenon, Zimmerman *et al.* (DOI: 10.1021/nn403897d) demonstrated quasi-epitaxial growth of an amorphous organic layer buried beneath the lattice of a self-assembled nanocrystalline organic cap layer after exposure to solvent vapor. The researchers used a combination of two squaraines as a donor layer, with crystallization seeded by the acceptor C_{60} cap layer subsequently deposited on top. After annealing by dichloromethane vapor, tests showed that the resulting crystalline interface hastens charge recombination, lowering the open-circuit voltage in an organic photovoltaic cell while increasing the short-circuit current. Controlling the degree of crystallization minimizes voltage loss, leading to high power conversion efficiencies. The authors suggest that this strategy could be used to boost power conversion efficiencies in photovoltaic cells made of other materials as well.