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Generating an Atmosphere

Dale P. Cruikshank

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cell contacts. This work identified a previously unknown function of the Pard3/JAM-C complex and shed light on a new mechanism involved in radial migration.

The radial migration of newborn granule cells starts with the extension of a process along thin radial fibers in the developing brain. This process emerges in front of the centrosome, which moves in afterward (*10*). Several models suggest that radial migration requires forward movements of the centrosome toward the tip of the elongating process and coordinated nuclear translocations (*11*). Several factors that can affect this process in granule cells have been identified. In particular, previous studies have shown that the protein Semaphorin-6A and its Plexin A2 receptor control the switch from tangential to radial migration and regulate the nuclear-centrosomal coupling (*12*). Nevertheless, the cell mechanisms and signaling pathways involved remain poorly understood.

Famulski *et al*. showed that Siah regulates the morphogenetic movements of granule cells through the post-translational regulation of the Pard3/JAM-C adhesive complex. A limitation of their findings, however, was that they could not directly demonstrate that the Pard3 protein is both translated and degraded by Siah-dependent ubiquitination in immature granule cells that are located near the surface of the brain structure. Indeed, as granule cells overexpessing Pard3 are induced to migrate radially, Siah invalidation that increases the Pard3 signal may also induce the exit of transfected cells toward deeper brain regions. Famulski *et al*. circumvented this difficulty by using in vivo imaging to visualize the extinction of a fluorescent signal linked to the degron motif of Pard3 in Siah-expressing cells located at the surface of the cerebellum.

Using the cerebellum as a model system, Solecki and colleagues shed light on a previously unknown mechanism to control neuronal migration from proliferative compartments. Interestingly, their results suggest that increased migration from the compartment is associated with reduced cell cycle exit. Repressing neuronal exit by posttranslational modification of a protein in a complex appears to be a very efficient means of quickly adapting both the proliferation and the migration of young neurons to environmental changes. It is now important to determine whether a similar mechanism controls the migration of embryonic neurons along radial glia in other brain regions, particularly in the cerebral cortex, and how it interacts with other guidance mechanisms. At the cellular level, another important question is how this new function of the PAR complex at the periphery of migrating neurons correlates with the function of the PAR complex function in the centrosome.

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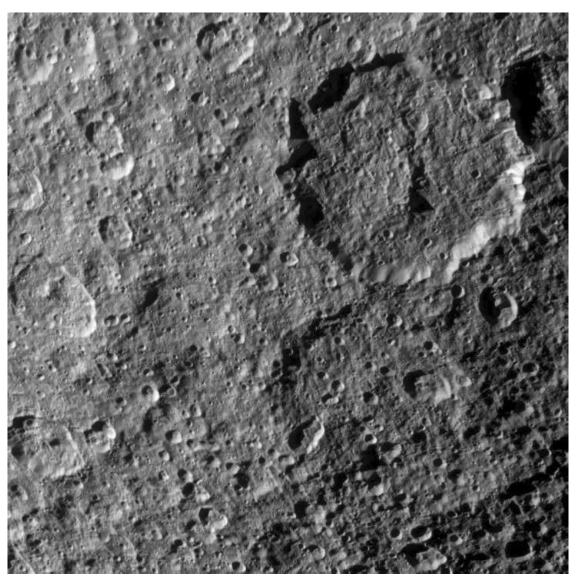
PLANETARY SCIENCE

Generating an Atmosphere

The oxygen and carbon dioxide atmosphere on Saturn's moon Rhea is produced by a photochemical reaction mechanism.

Dale P. Cruikshank

The presence of water ice on most of the large satellites of the outer planets was established many years ago through near-infrared (1- to 2.5-μm wavelength) observations with ground-based telescopes. Frozen carbon dioxide, sulfur dioxide, methane, nitrogen, and other molecular ices are also found in various combinations on inner planets such as Mars to bodies far beyond Pluto. Recent discoveries of ice varieties on some asteroids and sequestered in protected regions on Mercury and the Moon point to the near-universal distribution of frozen volatiles throughout the solar system (*1*–*3*). On page 1813 of this issue, Teolis *et al*. (*4*) report the detection of a tenuous (approximately one in five trillionth of Earth's atmospheric pressure at sea level) oxygen (O_2) and carbon dioxide (CO_2) atmosphere surrounding Saturn's icy moon Rhea (diameter of 1529 km) measured as the Cassini spacecraft passed by only 97 km above the surface in March 2010 (see the figure).



Rhea close up. Image in visible light on 17 October 2010 from a distance of 44,000 km above the moon's surface. The image was obtained with the Cassini Imaging Science Subsystem narrow-angle camera, showing ancient cratered terrain. The frame is 280 km on each side.

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The Ion Neutral Mass Spectrometer onboard Cassini captured a sample of Rhea's atmosphere and sorted the molecules by mass, confirming the presence of O_2 and CO_2. When these measurements are combined with data acquired by two other Cassini instruments on more distant flybys of Rhea in 2005 and 2007, a picture emerges in which O_2 formed by the irradiation of water ice is ejected from the surface by charged-particle interactions, and the tenuous gas is then swept away into space. These new results expand and clarify our understanding of the processes by which new molecules are synthesized, ejected, and then lost.

Solar system ices are not static deposits that remain undisturbed for all time. Ices in the interiors of planetary satellites and comets can warm, evaporate, and burst through

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the surface, sending jets of gas and dust into space, as we have seen emanating from Saturn's moon Enceladus and numerous comets. Ices exposed on the cold surfaces of outer planetary moons interact with the local space environment, as the incident solar ultraviolet light and charged particles from deep space and trapped in the parent planet's magnetosphere cause chemical changes in the ice and its evaporation into space by sputtering. Although these chemical changes occur at the molecular and even the atomic level, remote-sensing instruments on Earth and on passing spacecraft can detect them directly by optical (ultraviolet through infrared wavelengths) spectroscopy and by measurements from flybys high above the surface.

The origin of carbon dioxide is less clear, and requires either that CO_2 is native to Rhea's icy inventory, or that it forms at the surface from the released O_2 acting on carbon-rich grains. Such grains may be native to Rhea or entrained in its ice, but a more likely source is the carbonaceous micrometeorites that continuously dust the solid bodies of the solar system, including Earth.

In the tenuous O_2 atmosphere of Rhea, molecules rarely collide with one another, such that the rate of escape into space approximates the rate of ejection from the surface. Therefore, in the current epoch, the atmosphere is probably not increasing appreciably in density and surface pressure. However, Teolis *et al*. find that the rate of O_2 generation in the ice exceeds the rate of ejection from it, leading to the buildup of an oxygen reservoir. The episodic or long-term release of this stored oxygen could increase the total atmospheric density, but it would still be considered tenuous.

The presence of an oxygen-rich atmosphere of entirely radiolytic (photodriven) origin raises the question of using the detection of oxygen on an extrasolar planet as a criterion indicating the occurrence of life. The first detection of an oxygen-rich atmosphere on an extrasolar planet is likely to be accomplished by spectroscopy, which will require a somewhat denser atmosphere than Rhea currently has. It is notable, however, that emission of atomic oxygen in the tenuous atmospheres of Jupiter's moons Europa and Ganymede was detected by ultraviolet spectroscopy with the Hubble Space Telescope (*5*) and similarly in an extrasolar planet atmosphere (*6*). Additional laboratory and theoretical studies of O_2 production in ice by interaction with the nearby space environment and the development of a dense atmosphere should further clarify the feasibility of using this particular criterion, often cited as a hopeful sign of life in a remote planetary system (*7*).

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COMPUTER SCIENCE

Computational Physics in Film

Numerical modeling of how objects and fluids move, collide, and break up underlies spellbinding video animations.

Robert Bridson[1,2,3]* and Christopher Batty[1]

Computer simulation of solid and fluid dynamics underlies many visual effects seen in films produced during the past decade. This approach not only is less expensive than filming live action but also can avoid putting actors and crews in dangerous settings and can allow visualization of the impossible. Compared with more traditional animation methods that rely chiefly on artists' efforts, numerical solutions to the equations of physics allow computers to calculate realistic motion, such of that of smoke, fire, explosions, water, rubble, clothing, hair, muscles, and skin. Algorithmic advances now afford artists a higher-level, more efficient role in guiding the physics as they produce animation. We provide an overview here of current challenges in physics-based animation.

The movement and collisions of rigid bodies have long been the mainstay of physics-based animation, but modeling and integrating frictional contact remains a serious challenge. Structured stacks of blocks, highly nonconvex geometry, and delicate balances between pressure and friction all can pose torture tests for numerical methods that must exactly balance forces to keep these assemblies stable. Kaufman *et al*. (*1*) discuss new methods that use alternating projections (a way to calculate where interactions occur) to solve a constrained optimization formulation of contact.

Some objects, such as hair and clothing, are naturally deformable, which complicates the collision problem. In hair simulation, modeling the contacts between individual hairs creates a problem of computational scale. Resolving all of the collisions between the 100,000 hairs on a human head overwhelms brute-force methods. McAdams *et al*. (*2*) have taken a multiscale approach by treating hair as a continuum fluid, rather than discrete strands. This approach resolves the motion of the hair as a whole by averaging the motion into a continuous vector field, but truly accurate vector-field equations have yet to be derived. Kaldor *et al*. (*3*) have taken the opposite route in clothing simulation. Rather than use models that homogenize the two-dimensional (2D) surface of clothing, they perform a full simulation of every loop and twist in the yarn of knitwear and create subtle behaviors that simpler methods cannot reproduce. However, densely woven fabrics still require more efficient modeling as isometric surfaces, ones that bend but do not stretch or shear. English and Bridson (*4*) recently resolved the "locking" problem plaguing earlier efforts in which isometry constraints inadvertently prevent the natural bending. Paradoxically, their solution involves allowing holes to open up in the cloth between mesh triangles (the numerical regions into which the surface is decomposed). This finding poses interesting questions in discontinuous geometry, in that the mapping from surface parameters is neither continuous nor differentiable.

Volumetric elasticity—handling fully 3D deformation—is used in biomechanical models of the flesh of virtual creatures (*5*). Studios are rapidly increasing the anatomical detail of their models, from the complexities of muscles and tendons to delicate wrinkles in the skin. The amount of detail in the surface as well as the structures underneath the skin (muscles, tendons, bones, and other organs),

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