by an insect's compound eyes is fused with information on rotation rate from its ocelli, a trio of light-sensitive organs on its head[6].

Optic flow contains much richer information about an individual's motion and its environment than the authors exploit in this study, especially when sensed across the entire visual field[1,2]. It follows that widefield optic-flow sensing, coupled with a model more closely resembling the natural flight dynamics of insects, might not produce the same unobservability that de Croon and colleagues identify using their simple model of flight control. Even so, as their groundbreaking work shows, quadrotors and flapping fliers that use optic flow to control attitude can accommodate unobservability by embracing their wobble.

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Ecology

New catalogue of Earth's ecosystems

Brian J. McGill & Stephanie N. Miller

Echoing the hierarchical Linnaean system for naming species, ecologists have developed a definitive classification of Earth's ecosystems. This feat, achieved by a massive effort, could anchor conservation efforts for decades to come. **See p.513**

How should Earth's ecosystems be categorized in a systematic manner? On page 513, Keith *et al.*[1] propose a solution.

An ecosystem is a set of plants and animals and their associations with each other and the environment. A biome is a category of ecosystem whose members share similar vegetation structure and processes and are found repeatedly in different locations around the globe. Many examples of biomes, such as tropical rainforest, are immediately familiar, whereas others, such as succulent semi-desert, have names that are probably recognized only by an ecologist. And it might come as a surprise that ecologists would even bother to name certain biomes: for example, human-generated subterranean freshwater systems such as flooded mines.

The biome concept suggests that tropical rainforests can exist on different continents, have almost no species in common and yet look very similar to each other – a tall, dense canopy of mostly evergreen, broadleaved trees with many vines and most of the nutrients locked up in plants, rather than in the soil. Organizing ecosystems into biomes not only advances research, but is also crucial for conservation efforts. No government can feasibly create a policy without an inventory of what it is managing[2]. There have already been dozens of attempts to make an authoritative list of biomes, with each attempt having its own limitations.

Keith and colleagues have developed a list of six criteria for an optimal catalogue of ecosystem classifications. Finding no existing system that met all of these criteria, the authors assembled a series of committees to develop a new, definitive list under the auspices of the International Union for Conservation of Nature (IUCN), which is a large, influential non-governmental organization working in the area of conservation. The resulting classification system is called the Global Ecosystem Typology, hereafter referred to as IUCNGET.

Just as Carl Linnaeus developed a system for classifying organisms that uses subcategories such as kingdom, class, genus and species, IUCNGET has three main category levels: realm, biome and functional group. This new classification system identifies ten realms: four core realms (terrestrial, freshwater, marine and subterranean) and six interface realms that capture transitions between two core realms. These 10 realms are divided into 25 biomes, which are further subdivided into 110 functional groups that have more-subtle distinctions, driven by factors such as temperature, precipitation and seasonality. This system can be explored, complete with maps and pictures, at the website for this project (http://global-ecosystems.org).

A tropical rainforest, for example, would be in the terrestrial realm (denoted T), which is

A, DR MORLEY READ/SPL; B, GETTY; C, GETTY

Figure 1 | Classifying ecosystems. Keith *et al.*[1] present a new system for classifying any ecosystem on Earth. **a**, A tropical/subtropical dry forest and thicket, such as this one, has T1.2 as its ecosystem designation. This designation corresponds, respectively, to the terrestrial (T) realm, the first biome (a grouping of similar vegetation and processes) of this realm, and the second functional group of this biome. **b**, A succulent or thorny desert and semi-desert ecosystem, such as the example shown, is assigned to the ecosystem called T5.2 (for the second functional group of the fifth biome of the terrestrial realm). **c**, The ecosystem in this flooded quarry tunnel is placed in the SF2.2 grouping. It is in the subterranean–freshwater (SF) realm, the second biome of this realm, which is a human-generated biome, and its second functional group – flooded mines and other voids.

further subdivided into seven biomes, of which 'tropical or subtropical forests' is the first and so designated T1. Assignment to the tropical or subtropical lowland rainforests functional group completes the identification as T1.1 for one possible ecosystem. A tropical dry forest (Fig. 1a), distinguished by tall trees, many of which shed leaves during a relatively rain-free dry season, is in the same realm and biome as a tropical rainforest, but a different functional group (T1.2). A succulent semi-desert (Fig. 1b) would be classified as T5.2 (5 for the 'desert' biome and .2 for the 'succulent semi-desert' functional group). An underground freshwater flooded mine system (Fig. 1c) would be in the subterranean–freshwater (SF) realm. Specifically, it would be in SF2.2, which is the second (.2) functional group of the second biome of this realm — subterranean–freshwater in a human-generated landscape.

Two features of IUCNGET stand out as especially valuable. First, this system is truly comprehensive. Most of the previous classification schemes limited themselves to terrestrial[3] or marine[4] biomes only. Equally crucially, IUCNGET did not ignore human-created biomes — sites associated with farming, mines and so on are all included. This is arguably the first schema with which one could pick any point on the globe where life is found and map it back to one of the 110 functional groups.

Second, although the emphasis on both vegetation structure and processes has always been implicit in the idea of biomes, IUCNGET brings this combination front and centre. IUCNGET has a model (see Fig. 1 of ref. 1) with five categories of processes (resource drivers, ambient environment/climate, disturbance regimes, biotic interactions and human activities) that generate the defining ecosystem properties (for example, vegetation structure, vegetation seasonality, productivity, biomass and diversity).

This way of bringing processes to the forefront is particularly exciting. The link between climate and biomes has long been known[5,6] at a basic level, and an earlier, simpler effort[7] to make this connection has been extolled as providing one of ecology's most key generalities[8]. IUCNGET goes beyond just climate to include the four other categories of processes, and estimates the relative importance of the different processes for each of the 110 functional groups (see Fig. 3 of ref. 1). This required a colossal effort and a good deal of boldness in summarizing a vast amount of scientific literature. The authors almost certainly claim some generalities that will probably ultimately be proved false, but that in itself is useful — IUCNGET contains hundreds of hypotheses for ecologists to get excited about, test and prove or disprove.

The exercise of classifying biomes could easily seem like a highly detailed dive into ecological minutiae. Who but a bureaucrat gets excited about notations such as SF2.2? But we strongly suggest that these efforts, especially as epitomized in IUCNGET, are a major step towards generality in both applied and basic ecological research.

On the applied side, IUCNGET enables a move away from the individual tracking of each of the approximately 9,000,000 species living on Earth and towards identifying common processes that allow us to better predict how a biome will be affected by humans, and how human benefits (termed ecosystem services) derive from different biomes. It should also enable a transfer of knowledge about successful management practices between locations within a biome. The building of biome inventories also furthers the goal of the United Nations Convention on Biological Diversity of conserving ecosystems[9].

On the basic-research side, IUCNGET offers a way to start moving ecology past a crippling lack of generality that has arisen because of the complex reality of the dozens of forces acting on an ecosystem, ranging from predation to soil pH. Instead, IUCNGET moves ecology towards where scientists must end up — making and testing general, but conditional, claims regarding which processes are most crucial in which contexts[10–12].

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Astronomy

The gas about a famous quintet

Julia Blue Bird

A highly sensitive observation has revealed a large, diffuse gas feature centred on the galaxy group Stephan's Quintet — prompting a revision of our understanding of gas dynamics in the outer regions of galaxy groups. **See p.461**

The first dazzling images captured by the James Webb Space Telescope included a view of the galaxy group Stephan's Quintet[1]. Stars are often observed at the wavelengths accessible to optical and infrared instruments, but the gas in galaxies can be observed with ground-based radio telescopes, such as the Five-hundred-meter Aperture Spherical Telescope (FAST) in China. And it turns out that the gas in Stephan's Quintet has just as compelling a story to tell as do its stars. On page 461, Xu *et al.*[2] report using FAST to discover a gas feature, associated with the quintet, that lends weight to scenarios suggesting that objects outside the group might have influenced its formation history.

Galaxy groups are among the largest gravitationally bound structures to have been detected in the cosmic web of clusters, groups, filaments and voids that makes up the Universe[3]. Stephan's Quintet is located in the constellation Pegasus and seems to be an assembly of five galaxies. In fact, one of the five is much closer to us than are the others; the remaining four form the first compact group of galaxies ever discovered[4], a feat accomplished in 1877 by the French astronomer Édouard Stephan[5].

The group is so compact that the galaxies in it have started to interact. It lies around 92 million parsecs from Earth, a distance that is reasonably close in cosmic terms, at least compared with galaxies at distances of billions of parsecs. This proximity provides scientists with a front-row seat for witnessing interactions between galaxies and processes that are fundamental to galaxy evolution — and FAST is one of the key players in facilitating their observations.

With high sensitivity and substantial sky coverage[6], the 19-beam receiver of the telescope granted Xu *et al.* observations of