population into sub-groups with different fates (Fig. 1a).

Durdu and colleagues took a fresh look at FGFs in their study of the development of the zebrafish lateral line — a sensory organ that lies along either side of all fishes, allowing them to sense vibrations in the water. In this developmental process, about 100 cells (called the lateral-line primordium) start near the head-end of the embryo and, over a two-day period, collectively migrate along the entire length of the developing body under the skin towards the tail[6]. During this journey, subgroups of cells cluster together within the primordium. These are called rosettes, because the cells adopt a radial arrangement in which each cell has an extension towards an apparent central common connection point (Fig. 1b). As the primordium migrates along the body, it drops off these rosettes one by one at regular intervals. Each rosette goes on to develop into a discrete mechanosensory organ.

The authors knew that manipulating FGFs can affect the spacing of dropped organs[7], but not whether this was through a general effect on primordium velocity. They therefore quantified time-lapse movies of developing zebrafish embryos in which Fgf3 levels had either been upregulated by overexpression or repressed by drug inhibition. In both cases, they saw that the migratory velocity of the primordium was unaltered, which means that Fgf3 was affecting the drop-off frequency instead.

Having established a clear link between FGF signalling and rosette drop-off, Durdu *et al.* next explored where the signalling occurs. Fluorescence imaging of Fgf3 attached to green fluorescent protein suggested that it was localized into small, concentrated volumes at the apical centre of each rosette. Correlative microscopy (which combines fluorescence microscopy with electron microscopy) then revealed a striking cell-membrane arrangement: at the apical centre of each rosette was a microlumen formed by the cell membranes of all the cells of that rosette (Fig. 1c).

The researchers again used time-lapse imaging to show that the moment when Fgf3 starts to accumulate in a microlumen correlates with the time when that rosette begins to slow down in preparation for dropping out of the primordium. This pointed towards the intriguing possibility that FGF signalling is used on a very local basis to control the behaviour of just the 20 or so cells of one rosette. Durdu and co-workers went on to use all the advantages of the zebrafish system — ease of genetic modification and micromanipulation, and its suitability for high-quality time-lapse imaging — to test the idea.

They modified a single rosette so that one of its cells had increased Fgf3 levels (using either single-cell transplantation or a stochastic inducible genetic system), and observed that just this rosette was forced to drop out early from the primordium. On average, neither the rosettes before nor after it were prematurely dropped. To perform the opposite experiment, they punctured microlumina with a laser, thereby letting Fgf3 leak out. Satisfyingly, they observed the expected delay in rosette drop-off, again without affecting the previous or subsequent rosettes.

Several questions are not addressed in the study: for example, how the microlumina form in the first place; how levels of FGF expression are controlled; and, perhaps most directly relevant to the authors' findings, how FGF signalling accelerates rosette drop-off. But the strength of Durdu and colleagues' experiments is that single rosettes were manipulated *in vivo*, thus providing evidence that the microlumen can indeed restrict FGF signalling to the cells of just one rosette.

In this system, FGFs do not adopt one of their conventional upstream roles, in which a coherent swathe of different signalling levels splits a responding population of cells. Instead, the microlumen forces FGFs to take on a more downstream role: coordinating the response to a morphogenetic event, and ensuring that all cells of the rosette respond while none of the neighbours do. It is an intriguing case of multicellular architecture feeding back to control molecular signalling directly.

Because FGF concentrations accumulate only when the microlumen is topologically complete, the factors also provide a temporal checkpoint to the process. It thus unites a group of cells both temporally and spatially in a coordinated all-or-nothing response. This is an interesting, and slightly surprising, way to use a highly diffusible signalling molecule, but may turn out to be a widely employed mechanism in nature. ■

James Sharpe *is in the Systems Biology Program, Centre for Genomic Regulation, 08003 Barcelona, Spain; at the Universitat Pompeu Fabra, Barcelona; and at the Institució Catalana de Recerca i Estudis Avançats, Barcelona.*
e-mail: james.sharpe@crg.eu

1. Durdu, S. *et al. Nature* **515,** 120–124 (2014).
2. Dubrulle, J. & Pourquié, O. *Nature* **427,** 419–422 (2003).
3. Lander, A. *Cell* **128,** 245–256 (2007).
4. Häcker, U., Nybakken, K. & Perrimon, N. *Nature Rev. Mol. Cell Biol.* **6,** 530–541 (2005).
5. Dorey, K. & Amaya, E. *Development* **137,** 3731–3742 (2010).
6. Ghysen, A. & Dambly-Chaudiere, C. *Genes Dev.* **21,** 2118–2130 (2007).
7. Nechiporuk, A. & Raible, D. W. *Science* **320,** 1774–1777 (2008).

This article was published online on 22 October 2014.

ASTROPHYSICS

Monster star found hiding in plain sight

Massive stars are rare, but they are sources of some of the most energetic phenomena seen in the Universe today. A high-mass candidate has now been found in a star-forming region that has been observed for more than 50 years.

DONALD F. FIGER

The most massive stars in the Universe captivate the imagination of laymen and experts alike. They represent an extreme form of star and produce outsized effects on their environment. Although stars with masses greater than 20 times the Sun's mass comprise only about 1% of all stars in a young star cluster, their ionizing radiation, stellar winds and ejecta from supernovae dominate some of the most observable phenomena in the Galaxy. Massive stars are among the few bodies that can be seen in other galaxies, and they are probably linked to the most massive explosions in the Universe. Finally, they are thought to have seeded the early Universe with heavy elements (those heavier than helium), which are now seen in even the oldest stars. Writing in *Astronomy & Astrophysics*, Wu *et al.*[1] identify the next heavyweight contender — a star with the decidedly unsexy name of W49nr1.

Wu and colleagues claim a mass for this star that would place it among the most massive known, but a sceptic might say "extraordinary claims require extraordinary evidence". Indeed, astronomers have, on further inspection, often thrown such assertions on the rubbish heap of history.

This kind of claim relies on models that translate the amount of observed starlight into an estimate of the mass of the star. Generally, the more massive the star, the brighter it is. As is almost always the case, Wu *et al.* observe light from the star over only a fairly narrow range of wavelengths, representing much less than 1% of the total emitted light. It would be useless to convert that relatively small portion of the total light into a mass estimate were it

REF. 1/REF. 10

Figure 1 | Nestled in a young star cluster. The arrow indicates the location of W49nr1, a massive star identified by Wu *et al.*[1] in the central star cluster of the star-forming region W49. Scale bar, 1 arcminute.

not for the fact that the observed wavelength range contains several key spectral features (nitrogen and helium lines) that are powerful diagnostics of the temperature of the star. On the basis of the strengths of these features, Wu *et al.* find that W49nr1 seems to be one of the hottest stars known. With the temperature in hand, it is relatively straightforward to extrapolate the observed light to the total emitted light by using spectral energy distributions of well-studied massive stars.

Also crucial to the authors' assertion is an estimate of the distance to the star and of the absorbing effects of dust that lies between Earth and the object. A star might look bright merely because it is close to us, just as a nearby candle might look bright even though its power output is actually feeble. Likewise, a star might look faint simply because a large amount of interstellar dust lies between it and an observer on Earth. Wu *et al.* used an existing estimate[2] of the star's distance based on the relatively accurate method of trigonometric parallax, which had been applied to observations of radio signals, from sources called masers, that are associated with the excitation of water molecules in the star-forming region around W49nr1 (Fig. 1).

Another key requirement for this claim is that the light is emitted by a single star. In fact, the most common fate for claims that a massive star has been observed is the subsequent discovery that the light is actually produced by two or more stars, in which case the light from any individual star in the system suggests a star much less massive than proposed. One famous example is a star in R136, a star cluster in the Large Magellanic Cloud — a satellite galaxy orbiting the Milky Way. In this case, the putative supermassive star, which was predicted to weigh up to a few thousand solar masses[3,4], turned out to be at least a dozen stars[5]. However, some think that it contains several stars as massive as 150–300 solar masses[6]. If true, those stars would violate an apparent limit of 150 solar masses[7].

Another famous example is η Carinae, which is located in the Milky Way. It was once thought to be the most massive star known, but is now accepted to be composed of at least two stars. The mighty Pistol Star, near the centre of our Galaxy, is another potential heavyweight champion. It is known to be solo down to a very small distance, but it could still contain more than one star in a close binary system. There are insufficient data to determine whether the Pistol Star or any of the stars in R136 are coupled into multiple-star systems.

Taking all the uncertainties together, Wu and colleagues estimate that W49nr1 could have a mass of between 90 and 250 solar masses — quite a wide range. At the upper end, the star would be one of the few most massive stars known. The best estimate of stellar mass comes from observing eclipses in a binary system, when one star passes in front of the other, and applying Kepler's laws of orbital motion. Using this method, the most massive stars known are about 100 times more massive than the Sun[8].

As is often the case, the newly weighed star has been seen before; it lies in a massive young cluster of stars that was first reported[9,10] more than ten years ago and that is part of a star-forming region that has been studied for more than five decades[11]. It is only with new observations and a refined analysis that Wu and colleagues have been able to make their claim. Their work demonstrates once again that we know relatively little about massive stars because so few of them have been thoroughly studied. Indeed, even in regions that have been observed for more than 50 years, astronomers are still finding monster stars hiding in plain sight. ■

NATURE

50 Years Ago

Chromatography in Geology. By Arthur S. Ritchie — This slight text of around 50,000 words sails under false colours. It concludes with the statement that "in theoretical geology, chromatographic processes have become recognized as being of the greatest importance" — but all that is said on this topic amounts to no more than three short pages of obscure observations on gels and colloids … From the point of view of the academic geochemist, the omission of any reference to the importance of chromatographic techniques in recent American studies on palaeobiochemistry is equally striking. Perhaps it is understandable that no literature from the U.S.S.R. should be quoted, but to write on the role of gels in mineral genesis without even mentioning Chukrov's Russian-language monograph *Colloids in the Earth's Crust* seems strangely inadequate.
From *Nature* 7 November 1964

100 Years Ago

A further paper by Medical Inspector-General Delorme was read before the Paris Academy of Sciences on September 28, on the general subject of the treatment of wounds in war … The paper begins with a very welcome statement that the health of the French Army is excellent. "The persistent mildness of the weather since the war began, the extreme carefulness of the Government, the watchfulness of the Commands, from the lowest to the highest … the organisation and the regular methodical active working of the Army Medical Service, the great care given to the food-supply, the sites chosen for the troops — all these, up to now, have resulted in the maintenance of a perfect sanitary condition. The wounded Frenchman is a healthy man."
From *Nature* 5 November 1914

Donald F. Figer *is at the Center for Detectors, Rochester Institute of Technology, Rochester, New York 14623-5603, USA.*
e-mail: figer@cfd.rit.edu

1. Wu, S.-W. *et al. Astron. Astrophys.* **568,** L13 (2014).
2. Zhang, B. *et al. Astrophys. J.* **775,** 79 (2013).
3. Cassinelli, J. P., Mathis, J. S. & Savage, B. D. *Science* **212,** 1497–1501 (1981).
4. Feitzinger, J. V., Schlosser, W., Schmidt-Kaler, T. & Winkler, C. *Astron. Astrophys.* **84,** 50–59 (1980).
5. de Koter, A., Heap, S. R. & Hubeny, I. *Astrophys. J.* **509,** 879–896 (1998).
6. Crowther, P. A. *et al. Mon. Not. R. Astron. Soc.* **408,** 731–751 (2010).
7. Figer, D. F. *Nature* **434,** 192–194 (2005).
8. Chené, A.-N., Schnurr, O., Crowther, P. A., Lajus, E. F. & Moffat, A. F. J. *IAU Symp.* **272,** 497–498 (2010).
9. Conti, P. S. & Blum, R. D. *Astrophys. J.* **564,** 827–833 (2002).
10. Alves, J. & Homeier, N. *Astrophys. J.* **589,** L45–L49 (2003).
11. Westerhout, G. *Bull. Astron. Inst. Neth.* **14,** 215–260 (1958).

ECOLOGY

Diversity breeds complementarity

Evolutionary and ecosystem processes have long been treated as distinct. The finding that interactions among plant species cause rapid evolutionary changes that affect ecosystem function suggests that it is time for unification. **SEE LETTER P.108**

DAVID TILMAN & EMILIE C. SNELL-ROOD

The great naturalist Charles Darwin proposed his theory of evolution by natural selection as a unifying explanation for patterns seen in the natural world. But the unity sought by naturalists gave way to more-fragmented perspectives as natural history itself speciated into the modern disciplines of ecosystem ecology, community ecology, population biology, palaeontology and evolution. In this issue, Zuppinger-Dingley and collaborators[1] (page 108) have taken a significant step towards a reunification of these disciplines. Their findings in an experimental study of plants suggest that ecosystem and evolutionary processes cannot be separated: ecological interactions among a large number of plant species can cause rapid evolutionary changes that, in turn, influence ecosystem processes.

An idea central to both ecology and evolution is that of the niche — the set of environmental conditions in which a particular species thrives. In ecology, niche differences among species help to explain why large numbers of competing species coexist, and why greater plant diversity leads to greater ecosystem productivity[2]. In evolutionary biology, the niche concept features prominently in our understanding of how new species arise. Competition between closely related species drives the evolution of trait differentiation, such as bird beaks that are specialized for different seeds or lizard limbs that are suited for either climbing or walking. The evolution of such character displacement can be seen in laboratory experiments using microorganisms[3] and in field studies of incipient species formation, such as in Darwin's finches on the Galapagos Islands[4].

In their study of character displacement, Zuppinger-Dingley and collaborators made use of experimental field plots in which 16 species of grassland plant were grown either in monocultures or in mixed plots of 4 or more species for 8 years. They then collected these plants, propagated them in the lab, and assembled the offspring in new communities: either monocultures or mixed communities of two species. They observed that, relative to the monocultures, the 8-year period of selection in the high-diversity communities caused shifts in the traits of the plant species, specifically in plant height and leaf thickness. These shifts were consistent with character displacement and niche differentiation (Fig. 1a). The researchers also observed ecosystem-level consequences of these rapid evolutionary changes: the mixed cultures of plants from the diverse communities were more productive in terms of biomass than were mixed cultures from monocultures. These results exemplify the emerging field of eco-evolutionary dynamics, which emphasizes that not only does ecology drive evolution, but evolutionary change feeds back to affect ecological processes[5].

In Zuppinger-Dingley and colleagues' study, laboratory propagation of the plants increased the chance that the differences between the high- and low-diversity selection groups were due to genetic divergence.

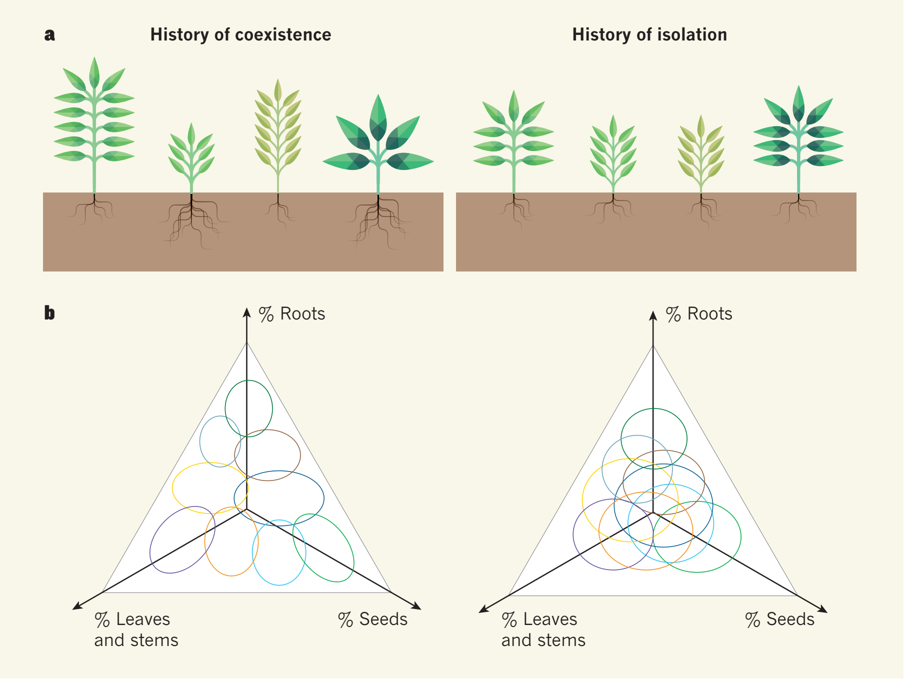

Figure 1 | Evolutionary niche shifts. a, Zuppinger-Dingley *et al.*[1] find that, when plant species are grown in a common environment, those that have a history of selection in diverse communities develop greater differences in traits (such as height and leaf thickness) than species that have a history of isolation. **b,** This idea feeds into our understanding of how evolutionary history influences the ecological interactions of species that compete for growth factors such as soil nutrients, light and space. All species face trade-offs. For instance, biomass that is allocated to obtaining soil nutrients (roots) cannot be used to obtain light (leaves and stems) or to disperse to open sites (seeds). Graphically depicted, the resulting 'trade-off surface' (triangles) represents all possible ways in which plant species (ellipses) can allocate their biomass. A history of selection in diverse communities results in greater interspecific differences (less overlap of ellipses) and more specialization (smaller ellipses) than a history of isolation.