embryonic development in a culture dish.

Pluripotent cells derived from human embryos, called embryonic stem (ES) cells, generally form poorly organized colonies when grown in culture. However, the group that performed the current study previously induced[5] ES cells to self-organize in a way that resembles early embryonic development. They achieved this by culturing the cells on circular micropatterns (microprinted discs of a material called extracellular matrix that is an optimal substrate for the cells) in the presence of the growth factor protein BMP4. The cultures formed endoderm and mesoderm but did not produce primitive streaks or node-like structures.

Martyn *et al.* took this strategy a step further. They successfully differentiated human ES cells into a node-like tissue by treating their micropatterned cultures with a combination of the growth factors Wnt and Activin, which are crucial for primitive streak and node formation in mice and other vertebrates[6,7]. This treatment led to the formation of a structure that showed characteristics of a primitive streak and to the induction of cells that produced organizer-specific proteins, such as Goosecoid[8].

To test whether this structure also has the functional characteristics of an organizer, the authors grafted its cells onto chicken embryos, in an area destined to give rise to extra-embryonic tissues that support embryonic development. Remarkably, the grafted cells organized into a notochord-like tissue and induced host cells to form elongated neural tissue (Fig. 1b), demonstrating that the grafted structure has the properties of an organizer.

One could argue that these experiments still raise ethical concerns because they are performed using human ES cells derived from an early-stage human embryo. However, pluripotent cells generated by reprogramming adult cells, which have essentially identical properties to ES cells, could be used as an alternative, alleviating this concern in future studies.

Martyn and colleagues' experimental system provides an alternative to using embryos to study the human embryonic node. Moreover, their experiments suggest that there is striking evolutionary conservation of organizer function from fish to humans. How the organizer organizes the surrounding embryonic tissues into an embryo remains poorly understood, for now at least. But the ability to produce organizer tissue in unlimited amounts *in vitro* will allow researchers to dissect organizer function at an unprecedented level. ■

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CLIMATE CHANGE

Tropical cyclones are becoming sluggish

The speed at which tropical cyclones travel has slowed globally in the past seven decades, especially over some coastlines. This effect can compound flooding by increasing regional total rainfall from storms. SEE LETTER P.104

CHRISTINA M. PATRICOLA

Tropical cyclones are among the deadliest and costliest of disasters (go.nature.com/2h59avp), causing destruction not only from strong winds, but also from flooding and mudslides associated with storm surges and heavy rainfall. The total amount of storm rainfall over a given region can be extreme, regardless of the maximum storm wind speeds; it is proportional to the rainfall rate and inversely proportional to the translation speed[1] (how quickly a tropical cyclone passes over a region). Some studies have investigated trends in heavy rainfall from tropical cyclones over the past century[2] and future projections in tropical-cyclone rainfall rates[3], but the translation speed has received less focus. On page 104, Kossin[4] investigates global trends in tropical-cyclone translation speed, and regional trends over individual ocean basins and adjacent land. He finds that translation speeds have slowed, suggesting that the total amount of regional rainfall from tropical cyclones might have increased.

> ***"The study finds a 10% global decrease in the speed at which tropical cyclones move."***

Kossin analysed 68 years of observations made from 1949 to 2016, the longest period for which global data on the locations of tropical cyclones were available. The uncertainty associated with observed trends in translation speed is minimal during this period, because the locations of the tropical cyclones are accurately known. By contrast, it is more difficult to detect trends in the number and intensity of tropical cyclones during this period, because some of these cyclones were not detected in the pre-satellite era[5] (before the 1960s). Kossin finds a 10% global decrease in tropical-cyclone translation speed over this period, a trend that withstands rigorous statistical testing and is dominated by tropical cyclones over the ocean.

The author found that changes in the translation speed of tropical cyclones over land — which are more relevant to society than those over the ocean — vary substantially by region. This is unsurprising, because only 10% of the original data are for such cyclones, and categorizing by region reduces the data sample further, making it more difficult to detect a signal among the noise. Nonetheless, statistically significant slowdowns of 20–30% have occurred over land regions next to the western North Pacific Ocean, the North Atlantic Ocean and around Australia.

Kossin's work highlights the importance of considering how global-scale atmospheric circulation can influence regional totals of tropical-cyclone rainfall. Tropical cyclones tend to 'go with the flow', meaning that the direction and speed at which they travel are guided by the winds in the surrounding environment. Therefore, any change in tropical circulation could conceivably affect tropical-cyclone translation speed, as Kossin reasons.

One limitation of this study is that it leaves open the question of what is happening to the rate of tropical-cyclone rainfall. The laws of thermodynamics reveal that, as the atmosphere warms by 1 °C, the amount of moisture it can hold increases by 7%. This suggests that global warming can enhance rainfall. However, it is unclear whether there are statistically robust trends in the total amount of regional tropical-cyclone rainfall, or how much the translation-speed slowdowns reported by Kossin could contribute to them. The availability and quality of data pose a challenge to our understanding of rainfall in general — the spatial distribution of rain gauges and radar observations of rainfall vary regionally, and satellite observations are limited to the past few decades and must be analysed using various assumptions to extract rainfall data. However, NASA/SPL

Figure 1 | Hurricane Harvey seen from space. The 2017 tropical cyclone known as Hurricane Harvey was particularly destructive, in part because it moved unusually slowly. Kossin[4] reports that the average speed with which tropical cyclones pass over a region has slowed since 1949.

if similar results are obtained from different data sources in overlapping periods, then any observed trends in rainfall can be considered to be robust.

Kossin's findings raise several questions, especially regarding 'stalled' tropical cyclones, which can be particularly destructive. Such cyclones are characterized by having an extremely slow translation speed (such as Typhoon Morakot[1], which moved over Taiwan with a translation speed as slow as 5 kilometres per hour in 2009), a track that recurves or loops over a region more than once (such as Cyclone Hyacinthe, which looped past the island of Réunion three times in 1980), or both (such as Hurricane Harvey, which meandered along the coast of Texas in 2017; Fig. 1). Kossin reports that the probability of tropical cyclones having translation speeds slower than 20 $\mathrm{km\,h^{-1}}$ is significantly greater in the latter half of the observation period. However, it is not known whether stalled cyclones have become more frequent, nor how natural variability and anthropogenic climate change might contribute to such a trend. It is also unclear whether the incidence of stalled tropical cyclones will change in the future.

As Kossin points out, part of the challenge in understanding variability and change in the occurrence of stalled tropical cyclones lies in the lack of a quantitative metric. Moreover, stalled tropical cyclones are relatively rare, making it difficult to evaluate whether there are statistically significant trends in the limited observations available. Statistical methods can help to quantify trends, but are sometimes less suitable for understanding the physical drivers.

Dynamic global climate models offer another solution to the problem of understanding stalled tropical cyclones. Computational simulations can represent current and future climates by changing the atmospheric concentrations of greenhouse gases and aerosols in such models. Dynamic models can also be used to separate the influences of natural variability and anthropogenic change. Advances in supercomputing now allow more global-climate simulations producing tropical-cyclone-like features than was previously possible. Collaborations between scientists studying tropical cyclones and those performing high-resolution climate simulations are thus producing valuable data sets[6,7], even though the climate models are imperfect. Computer software has been developed that quickly identifies tropical cyclones and their characteristics within the petabytes of model data generated by these efforts[8]. And although low-resolution global climate models represent tropical cyclones poorly, statistical-dynamic models[9,10] have been developed that use ocean and atmospheric states produced by such models as inputs for simulating tropical cyclones at low computational cost.

To strengthen the resilience of coastal and island communities to tropical cyclones, it is crucial to quantify and understand variability and change, not only in the number of tropical cyclones for different ocean basins, but also in the characteristics of tropical cyclones, including translation speed and its links with rainfall totals. Kossin's work paves the way towards developing this understanding, and raises questions that scientists can address using combinations of observations and modelling, to balance the benefits and limitations of each type of approach. ■

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