CellPress

11. Leca, J.-B. (2015). Arbitrary cultural behavior patterns are not unique to humans. Curr. Anthropol. *56*, 112–113.

12. Mazerolle, D.F., Hobson, K.A., and Wassenaar, L.I. (2005). Stable isotope and band-encounter analysis delineate migratory patterns and catchment areas of white-throated sparrows at a migration monitoring station. Oecologia *144*, 541–549.

13. DeWolfe, B.B., and Baptista, L.F. (1995). Singing behavior, song types on their wintering grounds and the question of leap-frog migration in puget sound white-crowned sparrows. Condor *97*, 376–389.

14. Searcy, W.A., Anderson, R.C., and Nowicki, S. (2006). Bird song as a signal of aggressive intent. Behav. Ecol. Sociobiol. *60*, 234–241.

15. Celis-Murillo, A., Stodola, K.W., Pappadopoli, B., Burton, J.M., and Ward, M.P. (2016). Seasonal and daily patterns of nocturnal singing in the Field Sparrow (*Spizella pusilla*). J. Orn. *157*, 853–860.

16. Odom, K.J., Hall, M.L., Riebel, K., Omland, K.E., and Langmore, N.E. (2014). Female song is widespread and ancestral in songbirds. Nat. Commun. *5*, 3379.

17. Kaluthota, C., Brinkman, B.E., dos Santos, E.B., and Rendall, D. (2016). Transcontinental latitudinal variation in song performance and complexity in house wrens (*Troglodytes aedon*). Proc. R. Soc. B *283*, 20152765.

18. Anderson, B.L. (2008). Migration, Accommodation, and Language Change: Language at the Intersection of Regional and Ethnic Identity (New York: Palgrave MacMillan).

19. Noad, M.J., Cato, D.H., Bryden, M.M., Jenner, M.N., and Jenner, K.C. (2000). Cultural revolution in whale songs. Nature *408*, 537.

20. Allen, J.A., Garland, E.C., Dunlop, R.A., and Noad, M.J. (2018). Cultural revolutions reduce complexity in the songs of humpback whales. Proc. R. Soc. B *285*, 20182088.

Ecology: The Patagonian Sun Dance

Natalia Perez Harguindeguy
Facultad de Cs. Exactas, Físicas y Naturales (Universidad Nacional de Córdoba) and Instituto Multidisciplinario de Biología Vegetal (CONICET-UNC), 5000 Córdoba, Argentina
Correspondence: natalia.perez.h@unc.edu.ar
https://doi.org/10.1016/j.cub.2020.06.066

Recent field experiments show how photodegradation and its legacy, increased microbial access to labile carbohydrates (photofacilitation), double rates of C loss to the atmosphere in a Mediterranean-type climate. The mechanisms demonstrated have implications for global C modeling beyond Mediterranean ecosystems.

Probably before preschool, we learn that sunlight is the fundamental energy source upon which life is built on this planet. Usually, later, we learn that the transformation of that energy in life, which starts with photosynthesis, ends its cycle in decomposition, the breakdown of dead beings. What is not in the common knowledge of kids is that sunlight can also play a role in the breakdown and decay of organic matter. Somehow, this gap in children's world view replicates the state of scientific knowledge — we understand much more about photosynthesis and productivity than we understand about decomposition in general, and the effect of sunlight on organic matter breakdown in particular. In fact, the effect of sunlight in breaking down matter, and its consequences on the C balance, has not reached mainstream attention until the last few decades. Now, we know that sunlight can have direct or abiotic effects (photodegradation or photolysis) on organic matter breakdown. In addition, sunlight can have indirect or biotic effects (photofacilitation or photopriming), a result of the activity of decomposers on the chemical changes driven by previous photodegradation. We also know that these processes can have a significant role in C dynamics, in both aquatic and terrestrial systems [1–3]. Based on some mechanistic understanding of those relationships, biogeochemical models have started to incorporate these processes [4]. However, to develop realistic models that fully account for the role of exposure to sunlight in the C cycle, we need a greater comprehension of the drivers behind and beyond this process, as well as how it can vary depending on the substrate, the climate and the decomposer communities [3].

Building on previous findings (e.g. [2,5,6]), a new article from Berenstecher and colleagues in this issue of *Current Biology* [7] presents strong and consistent evidence on the direct (photodegradation) and indirect (photofacilitation) effect of solar radiation on C cycling in a Mediterranean-type ecosystem. Based on a combination of complementary field manipulations, Berenstecher and colleagues demonstrate how the effect of sunlight can have a much higher impact on C release than previously detected, when photodegradation during the dry summer season is combined with the facilitation of biotic decomposition — through increased accessibility of litter polysaccharides — during the wet winter. Although these findings partially coincide with previous work, the experimental design of Berenstecher and colleagues gives us some hints on why, and how, the main drivers of decomposition swing from abiotic to biotic through the seasons of Mediterranean climate in Patagonia, as the effects of sunlight cross seasons (Figure 1).

The role of solar radiation on decomposition was proposed as a relevant process in the context of arid ecosystems more than 50 years ago [8].

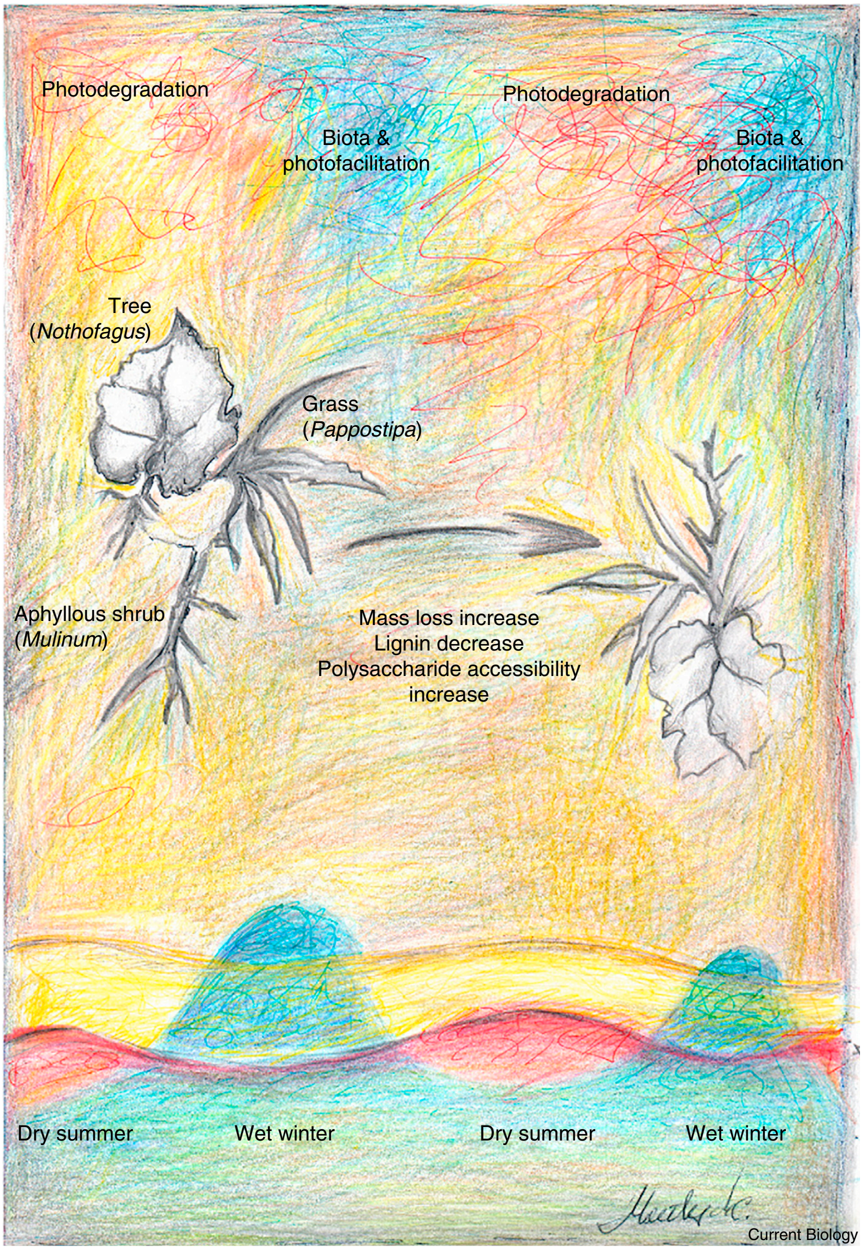

Figure 1. The cycle of sunlight-mediated degradation in a Mediterranean climate in Patagonia.
The drawing represents, from bottom to top: bottom: climatic oscillations in temperature (reddish line), rainfall (bluish line) and solar radiation (yellowish line) along 2 years in the Mediterranean climate Patagonia. Middle: the three growth forms 'leaves' used in the experiment (tree, grass, and aphyllous shrub) which, from left to right, decrease in size and definition representing changes in litter mass and in litter chemistry (decreased lignin content and increased accessibility to polysaccharides). Top: the seasons in which the effects of sunlight (photodegradation) not only dominate the dry summer but also 'permeate' in the wet winter (through the interaction of photofacilitation with biota). Artwork from Ma. Cristina Montes.

However, only in the last 15 years has it gained wider attention [3,9]. Initially, research into sunlight effects on decomposition was linked to the impacts of increased ultraviolet-B (UV-B) radiation as a result of ozone depletion in the 1980s [10]. Then, the main effects proposed for UV-B radiation were indirect (photofacilitation and negative impacts on microbial communities), while the ecosystems studied were those of high latitudes [11,12]. The interest in UV-B radiation has continued until present, as most plant compounds have a maximum absorbance in its range. However, now, we have multiple lines of evidence that UV-A (315–400 nm) and blue-green visible radiation (420–570 nm) may have an even greater role in decomposition than UV-B [5,13,14]. This is because, as most of UV-B is filtered by the atmosphere, there is much more UV-A and visible radiation reaching plant tissues than UV-B. Consequently, these wavelengths have been estimated to be responsible for 90% of the photochemical CO_2 emission [15].

Using full-sunlight field studies, Berenstecher and colleagues first show us how exposure to dry summer full sunlight can double litter mass loss across species of different quality, and independently of that litter quality, while biotic activity becomes the main driver of decomposition during the wet winter when differences in decomposition among species do relate to litter quality. These results provide strong field support for earlier findings [5,6] and constitute the basis on which the authors discriminate the effects of sunlight and biota in subsequent experiments.

In the second set of experiments, Berenstecher and colleagues demonstrate that, when leaf litter is exposed to full solar radiation during the dry summer, it decomposes faster during the wet winter (up to 100% faster, for the grass litter) than leaf litter that starts decomposition during the wet winter. This pattern is associated with a higher availability of polysaccharides in the litter that started its decomposition during the dry summer, as well as with a decrease in its lignin content. What is even more interesting is how the complementary experiments at the same time separate and integrate two of the main pathways by which sunlight interacts with leaf litter and biota on decomposition. By doing so, Berenstecher and colleagues defy the notion that experiments in natural conditions could hinder our understanding of sunlight's effects on decomposition because photodegradation and photofacilitation cannot be entirely distinguished [5,16].

In the third concatenated experiment, Berenstecher and colleagues take on the task of integrating the sunlight and biota effects over the long-term, a need systematically emphasized in the ecological literature. The results of the combined effects of solar exposure and biota over 2 years under the dry summers and wet winters of Patagonia show that solar radiation becomes the main driver of decomposition, doubling decomposition compared with attenuated radiation treatments. This strong effect could be related to the length of the experiment in combination with the fact that full sunlight was reaching leaf litter — the combination of these two experimental characteristics is difficult to find in field experiments.

The idea of sunlight breaking down material, either organic or inorganic, through different pathways is not absolutely new, particularly for arid ecosystems. Nevertheless, our understanding of the different and interacting effects of sunlight on C and nutrient cycling is fragmented, and research is still rather restricted to particular ecosystems. The findings of Berenstecher *et al.*, in the context of recent studies showing photodegradation and photofacilitation operating in cold, mesic, temperate and tropical ecosystems [17–20], expand the skies under which sunlight might be directly or indirectly driving decomposition. Although we are still far from having a clear picture of how the multiple effects of sunlight drive, or interact with the drivers of, the dynamics of growth and decomposition across time and space, these recent findings should motivate us to broaden our exploration of sunlight effects to any systems in which leaf litter is, at least seasonally, exposed to high sunlight. The integration of recent literature would indicate that, if there is sunlight, there are sunlight effects.

REFERENCES

1. Anesio, A.M., Tranvik, L.J., and Granéli, W. (1999). Production of inorganic carbon from aquatic macrophytes by solar radiation. Ecology *80*, 1852–1859.
2. Austin, A.T., and Vivanco, L. (2006). Plant litter decomposition in a semi-arid ecosystem controlled by photodegradation. Nature *442*, 555–558.
3. Austin, A.T. (2011). Has water limited our imagination for aridland biogeochemistry? Trends Ecol. Evol. *26*, 229–235.
4. King, J.Y., Brandt, L.A., and Adair, E.C. (2012). Shedding light on plant litter decomposition: Advances, implications and new directions in understanding the role of photodegradation. Biogeochemistry *111*, 57–81.
5. Foreid, B., Rivero, M.J., Primo, O., and Ortiz, I. (2011). Modelling photodegradation in the global carbon cycle. Soil Biol. Biochem. *43*, 1383–1386.
6. Austin, A.T., Méndez, M.S., and Ballaré, C.L. (2016). Photodegradation alleviates the lignin bottleneck for carbon turnover in terrestrial ecosystems. Proc. Natl. Acad. Sci. USA *113*, 4392–4397.
7. Berenstecher, P., Vivanco, L., Pérez, L.I., Ballaré, C.L., and Austin, A.T. (2020). Sunlight doubles aboveground carbon loss in a seasonally dry woodland in Patagonia. Curr. Biol. *30*, 3243–3251.
8. Méndez, M.S., Martinez, M.L., Araujo, P.I., and Austin, A.T. (2019). Solar radiation exposure accelerates decomposition and biotic activity in surface litter but not soil in a semiarid woodland ecosystem in Patagonia, Argentina. Plant Soil *445*, 483–496.
9. Pauli, F. (1964). Soil fertility problem in arid and semi-arid lands. Nature *204*, 1286–1288.
10. Zepp, R.G., Erickson, D.J., Paul, N.D., and Sulzberger, B. (2011). Effects of solar UV radiation and climate change on biogeochemical cycling; interactions and feedbacks. Photochem. Photobiol. Sci. *10*, 261–279.
11. Paul, N.D., Callaghan, T., Moody, S.A., Gwynn-Jones, D., Johanson, U., and Gehrke, C. (1999). UV-B impacts on decomposition and biogeochemical cycling. In Stratospheric Ozone Depletion: The Effects of Enhanced UV-B Radiation on Terrestrial Ecosystems, J. Rozema, ed. (Leiden: Backhuys Publishers), pp. 117–133.
12. Paul, N.D., and Gwynn-Jones, D. (2003). Ecological roles of solar UV radiation: towards an integrated approach. Trends Ecol. Evol. *18*, 48–55.
13. Austin, A.T., and Ballaré, C.L. (2010). Dual role of lignin in plant litter decomposition in terrestrial ecosystems. Proc. Natl. Acad. Sci. USA *107*, 4618–4622.
14. Brandt, L.A., Bohnet, C., and King, J.Y. (2009). Photochemically induced carbon dioxide production as a mechanism for carbon loss from plant litter in arid ecosystems. J. Geophys. Res.-Biogeosci. *114*, G02004.
15. Day, T.A., and Bliss, M.S. (2019). A spectral weighting function for abiotic photodegradation based on photochemical emission of CO2 from leaf litter in sunlight. Biogeochemistry *146*, 173–190.
16. Gliksman, D., Haenel, S., and Grünzweig, J.M. (2018). Biotic and abiotic modifications of leaf litter during dry periods affect litter mass loss and nitrogen loss during wet periods. Funct. Ecol. *32*, 831–839.
17. Brandt, L.A., King, J.Y., Hobbie, S.E., *et al*. (2010). The role of photodegradation in surface litter decomposition across a grassland ecosystem precipitation gradient. Ecosystems *13*, 765–781.
18. Liu, G., Wang, L., Jiang, L., Pan, X., Huang, Z., Dong, M., and Cornelissen, J.H.C. (2018). Specific leaf area predicts dryland litter decomposition via two mechanisms. J. Ecol. *106*, 218–229.
19. Pieristé, *et al*. (2019). Solar UV-A radiation and blue light enhance tree leaf litter decomposition in a temperate forest. Oecologia *191*, 191–203.
20. Marinho, O.A., Martinelli, L.A., Duarte-Neto, P.J., Mazzi, E.A., and King, J.Y. (2020). Photodegradation influences litter decomposition rate in a humid tropical ecosystem, Brazil. Sci. Total Environ. *715*, 136601.