SPECIAL FEATURE: INTRODUCTION

The dynamics of political polarization

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A number of trends in national and international politics greatly affect our capacity to achieve the cooperation that will be necessary to address the challenges facing society over the coming decades. These involve the interplay among partisanship and party loyalties within countries, populism, and polarization within and among nations. The trends are widespread and seem to be reshaping politics across the globe. They are inherently systems-level phenomena, involving interactions among multiple component parts and the emergence of broader-scale features; yet, they have been inadequately explored from that perspective.

To make progress in understanding these issues, political-science research stands to benefit from insights from other disciplines, including evolutionary biology, systems science, and the disciplines concerned with the fair and efficient provision of public goods of all kinds, but especially those affecting the shared environment and public health. These other disciplines, in turn, stand to gain equally from the perspective developed in political science. In viewing political systems as complex adaptive systems, we can gain a new understanding of the forces that shape current trends, and how that knowledge might affect governance strategies going forward. Extreme polarization is a dangerous phenomenon that requires greater scientific attention to address effectively.

This Special Feature of PNAS draws on this relatively new interdisciplinary field, featuring original joint research from collaborating political scientists and complex systems theorists. Each paper is a true partnership among the different disciplines and illustrates the benefits of closer ties between complex systems and social science. The papers explore the emergence of patterns and structures in societies and the linkages among individual behaviors and societal benefits across scales of space, time, and organizational complexity. The COVID-19 pandemic provides the most recent examples of how patterns of polarization in societies interact with our abilities to solve societal challenges.

The main goal of the Special Feature is to deepen our understanding of the dynamics of political polarization and related trends, and especially the interplay among these processes at multiple scales, from the local to the international. The papers cover many different aspects of this issue and do so from different systems-level perspectives, providing a broad view of the problem. The papers explore the impact of information flow networks, the diverse nature of national governance systems, the role of the media, and the dynamics of party sorting. They pose a number of key questions. Do the dynamics of such systems follow a natural progression of polarization and collapse, similar to Schumpeter's economic theories [1]? How do migration, globalization, and new technologies, such as the internet, affect the trends? Does an extension of Duverger's Law [2] foreshadow a natural tendency toward polarization in nations with two-party systems, like that in the United States, undercutting Madison's dream [3]? Duverger's Law argues that a system like that of the United States, based on a plurality rule on a single ballot, will lead to a two-party system, while Madison hoped for a system that would "break and control the violence of faction" [3].

The Special Feature arose from a series of workshops in which the issues were aired, collaborations were developed, and earlier versions of the papers received constructive feedback. It became clear from those discussions that even the definition of polarization has manifold aspects, that some degree of polarization is likely healthy in sharpening issue differences in any society, and that there have been historical fluctuations in polarization at all levels, within and among nations and peoples. What is clear, though, is that it is essential to understand the causes and consequences of polarization if we are to deal with regional, national, and global problems that we will face in the coming years.

The Special Feature includes 11 individual articles, incorporating both novel research and Perspectives. In addition, Jenna Bednar [4] provides a Perspective embedding the contributions within the

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context of Madison's dream. Delia Baldassari and Scott Page (5) also provide an interactive Perspective, joining together their individual views on the issues considered and responding to one another's. Since the papers are covered in detail in these commentaries, we provide only a brief introduction to the topics covered.

Axelrod et al. (6) set the stage by highlighting the threats that polarization presents to democracies, and ask via an agent-based model whether the dynamics of polarization can reach a threshold level at which it becomes a runaway process, and whether interventions can stem the tide. Their model is based on the assumption that interactions between similar actors will reduce their differences, and that the opposite is true for interactions between dissimilar actors. More specifically, they explore the effects on polarization of factors, such as level of tolerance to other views, exposure to dissimilar actors, and economic shock, among other influences.

James Madison, one of the principal architects of the United States system, had worried about polarization and the role of political parties and tried to design the system to avoid factionalization (3). Our present dilemma shows that his plan was flawed. Kawakatsu et al. (7) take a bottom-up approach to show how partisanship affects the likelihood that individuals learn from others. They find that when individual opinions are heavily shaped by peers, increasing partisan bias leads to factionalization around a reduced number of issues and to polarization.

Leonard et al. (8) focus on the polarization of elites, meaning elected officials, exploring reinforcement mechanisms and subtle differences between Republicans and Democrats that are the result of asymmetric polarization. They show that small polarization differences in public opinion can influence self-reinforcement of relevant attitudes among the elites, that tipping points can occur at which polarization speeds up, and that Republicans seem to have already passed the critical threshold while Democrats are approaching it. Such tipping points also occur elsewhere in this volume, for example in the paper of Axelrod et al. already discussed (6), and in Macy et al. (9), which also focuses on political elites.

Perrings et al. (10) ask how polarization at the national level affects international cooperation in the provision of environmental public goods. While the network of international environmental agreements has been characterized as a complex adaptive system, there is yet no consensus on the determinants of national interactions in individual agreements. They show that while party polarization reduces national support for international agreements, stakeholder engagement can have a moderating effect, whether or not stakeholders are themselves polarized.

The international focus continues with the paper by Chu et al. (11), which examines through the lens of Ukraine how local variation in attitudes can complicate the dynamics of polarization, in particular in relation to the European Union. Using a version of the adaptive voter model, they explore how political shocks can play out differently in different regions of a country based on the preexisting context of attitudes and interaction networks.

Macy et al. (9) develop an agent-based model of polarization, focusing on a phase analysis of elite opinion. Their model of opinion dynamics, following from that of Axelrod's 1997 paper (12) and Axelrod et al. in the current volume (6), shows that tipping points can emerge and, even in the face of significant external threats, prevent any return to an earlier equilibrium. Agents following rules of positive and negative influence and homophily interact to produce different levels of

polarization. In this process, they demonstrate that political polarization can become self-reinforcing and accelerate over time into an unstoppable process. While numerous tipping points exist in the model, there is a tendency for asymmetric ones to emerge in which polarization, once started, becomes a runaway process. Strikingly, even common shocks may not reverse this process.

Santos et al. (13) focus on online social networks, exploring how individuals may be influenced in their attitudes by the recommendations of those with whom they are linked on those networks. They show that preferentially linking with structurally similar nodes can lead to polarization through the creation of echo chambers. By contrast, preferentially linking to structurally dissimilar nodes has the opposite effect, moderating the opinions of linked individuals. The results have interesting implications for the design of interventions to curb polarization.

Stewart et al. (14) show how affective polarization, in which individuals in one group develop strongly negative views toward those in other groups, can result from cultural influences, and show how mechanisms of wealth redistribution can limit polarization. They develop a model of cultural evolution to explore how factors such as social inequality, economic hardship, and racial animosities interact with party cleavages to generate and maintain affective political polarization. They go on to show how wealth redistribution by providing public goods can ameliorate the situation and reduce polarization.

Tokita et al. (15) further explore social networks, and specifically the role of the information network in driving polarization. They present a model in which individuals gain information through their social networks, and potentially change their networks based on the information cascades to which they are exposed. Polarization of the social networks is then an outcome, and echo chambers result in which individuals hear the news they want to hear.

Vasconcelos et al. (16) address the question raised at the beginning of this introduction, namely the effect of polarization on achieving collective benefits for a society. They show that when polarization implies heterogeneous preferences, it can be beneficial. But when it implies segregation of the social network and impedes information about the preferences of people other than close neighbors, it can be harmful. When local networks distort the value of the benefits of cooperation or coordination, those networks reduce the likelihood that it will occur. One such outcome is the undermining of democratic processes.

Wang et al. (17) seek to better understand three key features of the United States political system: low dimensionality, elite polarization, and antimajoritarianism in legislatures. They show how specific rules, agents' interactions in networks, and the effects of exogenous factors can combine to create emergent behaviors, such as nonlinear relationships, history-dependence and hysteresis, and sudden transitions (criticality). They touch on how a complex system might create these three problematic features of the United States polity. But most importantly, they reflect on what types of measures could plausibly be used to reverse these failings.

Polarization is a process and that is what complexity theory can best help us understand. Complexity models can trace dynamics through time given some assumptions about actors' behavior, and show possible system trajectories for polarization. The evolution of the system as parameters change and feedbacks occur is key. Each model in the Special Feature makes specific assumptions, and then is set in motion to see how it

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evolves, thereby showing what can happen to polarization under varying circumstances. The Axelrod et al. paper (6), for example, looks at how a number of different conditions shape the trajectory of polarization when guided by the standard attraction–repulsion model. Notably, they show that more attention to economic self-interest and less exposure to opposing views reduces the likelihood of extreme polarization trajectories. Leonard et al. (8) show how, over time, positive feedback loops between elites and public opinion drive polarization among elites. Past a critical threshold, the polarization process can reach extremes and can become very asymmetric. Macy et al. (9) also show how the political systems can be driven into extreme polarization and, like Axelrod et al. (6), find that even large common shocks—such as a pandemic, economic collapse, attack by a foreign adversary, or impending climate catastrophe—are often unable to stop the dynamics of accelerating polarization.

Perrings et al. (10) demonstrate how national commitments to international cooperation evolve over time as polarization changes. The dynamic process of cooperation with other nations suffers as domestic polarization grows. Santos et al. (13) focus on social network communities and what makes them polarize. As the structure of the network evolves over time, rewiring people according to their structural similarity, polarization or convergence can occur depending on the conditions. Chu et al. (11) focus on local discussion networks and their influence on attitudinal polarization. Via these networks, political shocks can influence polarization, possibly increasing it, on multiple scales. Vasconcelos et al. (16) focus on coordination and the impact on it of the properties of the networks that connect individuals. Coordination can, under some conditions, lead to collective action, but this work shows how it can also undercut efforts at achieving a social optimum.

Stewart et al. (14) use a model of cultural evolution to reveal how economic interactions can affect polarization. Risk aversion and inequality can produce a runaway process of polarization over time. Using computational models on social media data, Tokita et al. (15) model how information cascades can reorder social ties and lead to increasingly polarized networks. The evolution of the system in these models is of most importance. The different factors that might exacerbate or reduce polarization are explored here, as are different systems. Policy can be better informed by showing how different parameters speed up or slow down polarization in different types of systems. Finally, Wang et al. (17) do not develop a model, but do explore the lessons learned from modeling studies for implementing more effective reforms. A benefit of complex systems models, they argue, is that they can be used to test how reforms interact with the system, whether they can be helpful, and whether they generate unintended consequences.

The essays here bring a different perspective to bear on the issue of political polarization from the usual one in political science. A central theme is the loss of diversity that extreme polarization creates, where diversity encompasses both the range of salient issues addressed and the richness of the options considered in addressing each issue. The collapse of multidimensional issue space and the alignment of people to the two parties symbolizes a loss of important diversity. As environmental and complexity scientists have shown in other contexts, diversity maintenance is critical for many systems to thrive and often to survive at all. Democracy, which is a system built on diversity, is also a system built to manage diversity. A complex adaptive systems approach highlights this view. It also brings forward other ways of seeing the emergence and evolution of political polarization. Concepts like feedback loops, phase transitions, thresholds, and irreversibility are ideas from this approach that can help us understand the dynamics of polarization. The papers included here focus on these dynamic properties and lend a different and distinct perspective to our studies of polarization.

The essays also indicate why the phenomenon is a cause for concern. The loss of diversity they describe has implications for the capacity of the system to deliver public goods. It circumscribes both the range of public goods considered to be admissible and the scope for cooperation in the supply of those public goods. This effect plays out at every level of governance, from local to global. The mechanisms by which polarization compromises public-good provision differ at different levels of governance and in different systems, but the effects are quite general.

The two Perspectives (4, 5) signal both the synergies between the papers and the research agenda they open up. They show how the papers, taken together, build a picture of the interactions between ideological and affective polarization and issue dimensionality. But the overall picture is largely restricted to a particular system, the United States, and a particular scale. We learn mostly about interactions among individuals within the United States. Extending the analysis to multiple scales and multiple systems would be potentially rewarding, and we hope the papers in this issue will stimulate more international work. Within the United States, federalism allows a diversity of ideas, issues, instruments, and institutions that provides a check on runaway polarization. At the global scale, where the status quo is affective polarization built around race, language, culture, and nationality, institutions of international governance play a much weaker role. The challenge is to develop an approach that explores the emergent properties of cross-scale interactions at higher levels of governance to understand the implications of polarization at the federal level and beyond.

1 J. A. Schumpeter, *Capitalism, Socialism and Democracy* (Routledge, New York, 1994).
2 M. Duverger, *Political Parties: Their Organization and Activity in the Modern State* (Methuen, London, 1964).
3 J. Madison, "The Federalist Papers: No. 10" in the Avalon Project (Yale Law School, New Haven, CT, 2008). https://avalon.law.yale.edu/18th_century/fed10.asp. Accessed 16 November 2021.
4 J. Bednar, Polarization, diversity, and democratic robustness. *Proc. Natl. Acad. Sci. U.S.A.* **118**, e2113843118 (2021).
5 D. Baldassarri, S. E. Page, The emergence and perils of polarization. *Proc. Natl. Acad. Sci. U.S.A.* **118**, e2116863118 (2021).
6 R. Axelrod, J. J. Daymude, S. Forrest, Preventing extreme polarization of political attitudes. *Proc. Natl. Acad. Sci. U.S.A.* **118**, e2102139118 (2021).

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7 M. Kawakatsu, Y. Lelkes, S. A. Levin, C. E. Tarnita, Interindividual cooperation mediated by partisanship complicates Madison's cure for "mischiefs of faction." *Proc. Natl. Acad. Sci. U.S.A.* **118**, e2102148118 (2021).

8 N. E. Leonard, K. Lipsitz, A. Bizyaeva, A. Franci, Y. Lelkes, The nonlinear feedback dynamics of asymmetric political polarization. *Proc. Natl. Acad. Sci. U.S.A.* **118**, e2102149118 (2021).

9 M. W. Macy, M. Ma, D. R. Tabin, J. Gao, B. K. Szymanski, Polarization and tipping points. *Proc. Natl. Acad. Sci. U.S.A.* **118**, e2102144118 (2021).

10 C. Perrings, M. Hechter, R. Mamada, National polarization and international agreements. *Proc. Natl. Acad. Sci. U.S.A.* **118**, e2102145118 (2021).

11 O. J. Chu, J. F. Donges, G. B. Robertson, G. Pop-Eleches, The microdynamics of spatial polarization: A model and an application to survey data from Ukraine. *Proc. Natl. Acad. Sci. U.S.A.* **118**, e2104194118 (2021).

12 R. Axelrod, The dissemination of culture: A model with local convergence and global polarization. *J. Conflict Resolut.* **41**, 203–226 (1997).

13 F. P. Santos, Y. Lelkes, S. A. Levin, Link recommendation algorithms and dynamics of polarization in online social networks. *Proc. Natl. Acad. Sci. U.S.A.* **118**, e2102141118 (2021).

14 A. J. Stewart, J. B. Plotkin, N. McCarty, Inequality, identity, and partisanship: How redistribution can stem the tide of mass polarization. *Proc. Natl. Acad. Sci. U.S.A.* **118**, e2102140118 (2021).

15 C. K. Tokita, A. M. Guess, C. E. Tarnita, Polarized information ecosystems can reorganize social networks via information cascades. *Proc. Natl. Acad. Sci. U.S.A.* **118**, e2102147118 (2021).

16 V. V. Vasconcelos *et al.*, Segregation and clustering of preferences erode socially beneficial coordination. *Proc. Natl. Acad. Sci. U.S.A.* **118**, e2102153118 (2021).

17 S. S.-H. Wang, J. Cervas, B. Grofman, K. Lipsitz, A systems framework for remedying dysfunction in US democracy. *Proc. Natl. Acad. Sci. U.S.A.* **118**, e2102154118 (2021).