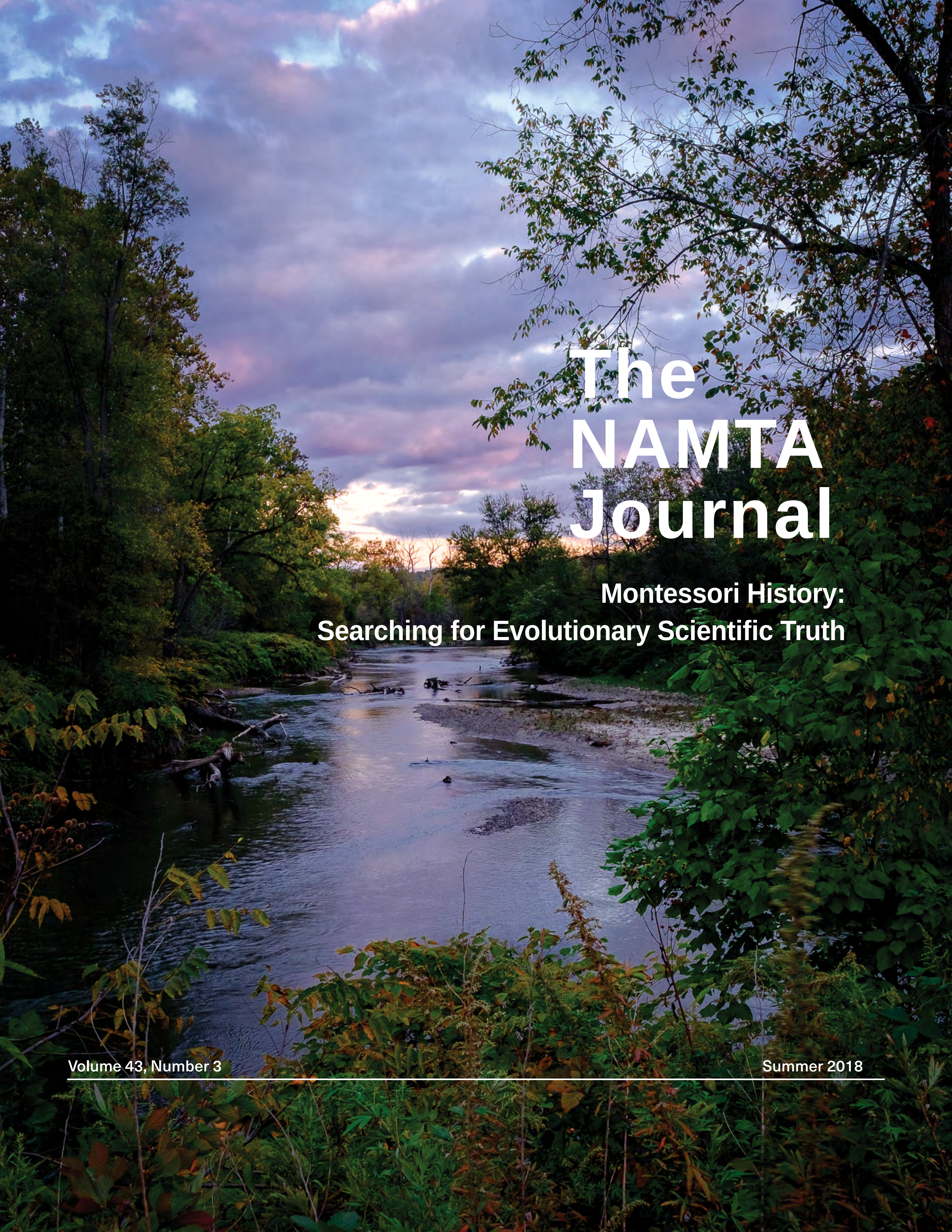

The NAMTA Journal

Montessori History: Searching for Evolutionary Scientific Truth

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MONTESSORI HISTORY: SEARCHING FOR EVOLUTIONARY SCIENTIFIC TRUTH

WHAT IS NAMTA?

The North American Montessori Teachers' Association provides a medium of study, interpretation, and improvement of Montessori education. These purposes are accomplished through a widespread communication system of periodicals, an audio visual library, workshops, and research. NAMTA endeavors to create real services designed for the teacher and the school.

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Montessori History:
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PREFACE

Photo by Christian White

David Kahn introduces Baiba Krumins Grazzini at NAMTA's 2018 Cleveland conference.

Montessori History: Searching for Truth

History Makes a Joyful Noise

by David Kahn

The introduction of NAMTA's 2018 Cleveland conference stated, "David Kahn set out to personally orchestrate his last conference for NAMTA with a stellar cohort of great Montessori commentators on history and life sciences. Speakers will present Montessori history, anthropology, the crafting of key lessons, the weave of history and pioneer ecology, and hypothetical framing questions. Compelling teaching materials span everything from contextualized historical thought to Montessori's psychological rendering of all disciplines through the history lens."

This conference unpacked and celebrated the realization of the deepening vision that Maria Montessori forecasted in 1907. "I had a strange feeling that made me announce emphatically at the opening that here was a 'grandiose' undertaking of which the whole world would one day speak" (*The Secret of Childhood,* Sangam Books, 2001, 118). Montessori's continuity of work has been revealed by current adolescent research. Her vision develops the formation of a profoundly aware Montessori adult imbued with a deep human purpose in a global context. A Montessori historical definition of post-Darwinian evolution depicts humans in symbiosis with all life on Earth. In this journal (p. 84), Lynn Margulis further explains her living Earth (Gaia) theory of mutualism and reciprocity between all life and the environment. Montessori's broad treatment of history as a meta-discipline not only uncovers sequences of improved understanding of the human-built and natural environments, but also analyzes present trends and predicts a future geopolitical web. This intersection of environment and politics has become inseparable, and David Orr (p. 24) implores that political, historical, and economic knowledge is imperative if we are to truly prepare students to be dedicated to the causes of humanity, justice, and the environment. Montessori's scientific approach has arrived in the twenty-first century. The child's comprehensive developmental knowledge prepares solid ground for future generations in an ever-changing natural and humanly constructed world. History is waiting to be discovered in the unfolding of the 100 year-old vision of Maria Montessori. Her deepening integrated material through history is plotted line by line in her philosophy of biology, geology, astronomy, chemistry, evolution, mathematics, and environmental balance without a simplistic reduction to a clichéd motto such as "go forth and save the world." In the last decade, Montessori's visionary education for peace and the emergence of the concept of psycho-discipline, "the study of a discipline-based learning mode on the psychology of the child" (Baiba Krumins Grazzini, Chicago Adolescent Orientation 2018, unpublished), is coming to fruition. The global benefits of an internationally connected philosophy of education through scientific study and physical work has woven a transdisciplinary field that "spans the big bang through the future." On page 63, Laffitte introduces the content and ideas of Big History, which is taught at all levels throughout the world, and shares resources for classrooms. This revelation of the common truth jointly studied in order to understand the origins of the unifying narrative of natural history and civilization was fortified at the 2018 Cleveland conference by a presentation on Big History by Lucy Laffitte and Eric Chaisson. Montessori education needs freedom from assignments and fixed study within the four walls of the classroom to become a more expansive vision for its secondary education.

Montessori schools are emerging in a postmodern era where learning by doing, locally, and through hands-on, globally connected activities are all essential to preparation for adult life. This focus on work in an international community becomes more effective in reshaping the design of Montessori elementary and secondary intellectual education. In the Montessori study of history, fact is aligned with human optimism, maturity, authentic personal dignity, and the cosmic view of all interdependent life on Earth. These are not academic goals or knowledge managed by objectives. These insights are dynamic eco-activist fables prepared by story tellers of the truth as discussed by Gerald Leonard, Kathleen Allen, and Baiba Krumins Grazzini in this journal.

The Cleveland conference was presented in the perfect venue for its message: within the walls of the Cleveland Museum of Natural History. The timeless narratives of the human endeavor are discussed and presented in this journal's texts.This conference made a joyful noise about the current positive belief in the human personality, and about the future of Montessori education, which is looking to touch on a real, organic connection as part of an evolving reality of human solidarity.

This last journal of my NAMTA executive career is a reflection in the flow of Montessori thought that has been witnessed by the NAMTA community, the NAMTA board, my wife Barbara, NAMTA members, close friends, and kindred guest speakers from far and near, all coming together. They reflect their ownership for entering into the flowing river of Montessori ideas in 2018, side by side, in the context of their own wisdom in teacher practice. The blossoming of a great educational vision is anticipated for 2019 and in perpetuity. Heraclitus, the pre-Socratic Greek philosopher (c. 535–475 BCE) was famous for his saying, "No man ever steps in the same river twice." Montessori is changing, yet paradoxically the same. Montessori's unfolding history is being proclaimed by Montessori troubadours of our time who continue their charge and provide a place in time to stop and observe a vision that is forever processing in wonder and awe. We stand here, and that is all Montessori denominations need to do: Stand together in our time, in the here and now, and materialize the difficult-to-reach intangibles that we have to keep alive. This NAMTA journal's magic prevails because it is more than a clinical recording of proceedings; The NAMTA Journal has been more than scholarly or sentimental. John Wyatt coined a term for exploring pedagogical direction of Montessori education, a double yellow brick road, that both leads and preserves the real depth, breadth, and love of the Montessori examined life of both the teacher and the student.

Thank you all for making my Montessori career so rich with your appreciation, help, and support. In this journal, I am giving back, yet our Montessori visionary work remains unfinished and needing to be made more actualized for the future.

PLACE-BASED EDUCATION AND CITIZEN SCIENCE: RESOURCES FOR LEARNING BEYOND THE CLASSROOM

Louise Chawla *is professor emerita in the program in environmental design at the University of Colorado Boulder. She remains active in the university's Community Engagement, Design and Research Center, which she helped establish and which includes the Growing Up Boulder program to involve children and adolescents in participatory planning and design with city agencies. This program is the foundation of the recent book* Placemaking with Children and Youth: Participatory Practices for Planning Sustainable Communities *(New Village Press, 2018), which she co-authored with her colleagues Victoria Derr and Mara Mintzer. Chawla began her career as a Montessori primary and elementary teacher. She received her training from Phoebe Child and Margaret Homfray, who helped Maria Montessori spread the Montessori Method in Great Britain and who established the St. Nicholas Training Center in London, during a period when they led training courses in Pennsylvania in the summers.*

Abigail White *is the on-site naturalist and support director at Forest Bluff School in Lake Bluff, IL. She works with all levels, young children's community through secondary level, to connect children with nature, both at school and in the surrounding community. White has a bachelor's degree in biology from Illinois Wesleyan University and a master's degree in plant biology and conservation from Northwestern University. She most recently worked at the Chicago Botanic Garden as a research assistant on various wildlife conservation projects. Her master's work focused on the commercial availability of native plants and the conservation genetics of a rare thistle species. One part of her master's thesis was recently published in the scientific journal* Restoration Ecology, *under the title "Restoring species diversity: Assessing capacity in the U.S. native plant industry" (White et al., 2018). White is currently enrolled in the Montessori Institute of Milwaukee's satellite elementary training in Chicago, IL.*

PLACE-BASED EDUCATION AND CITIZEN SCIENCE: RESOURCES FOR LEARNING BEYOND THE CLASSROOM

by Louise Chawla and Abigail White

This fully documented article about place-based education and citizen science offers annotated sources that can be used for Montessori programs at all levels and in all settings for site selection and curriculum connections. This compilation of resources can serve as a practical tool kit for organizing place-based learning in schools. The reader can enjoy this chapter by reading through from beginning to end or can simply go directly to the resources that are organized by type and topic.

From the beginning, life in the early Children's Houses flowed out of the classroom into the surrounding world. Even at the first Children's House in a bleak tenement district of Rome, Maria Montessori believed that one of the circumstances that contributed to its success was that the children could enjoy the building courtyard with pleasant grassy spots and trees (*The Secret of Childhood* 143, 167). At each stage of a child's development, she noted, "To go out of a classroom to enter the outside world, which includes everything, is obviously to open an immense door to instruction. . . . Let us take the child out to show him real things. . . ." (*From Childhood to Adolescence* 33, 34).

Learning beyond the classroom was also promoted by the progressive philosophy of John Dewey in the early twentieth century. Dewey believed that schools should encourage children to follow their interests, raise questions, collect and analyze evidence to find answers, develop ideas and suggestions, apply their ideas to test their value, and reflect upon results—and do this with others in a spirit of community and service to the world (Dewey, *Democracy*). A primary responsibility of educators, he claimed, is to "know how to utilize the surroundings, physical and social, that exist so as to extract from them all that they have to contribute to building up of experiences that are worthwhile" (Dewey, *Experience* 40). These ideas promoted project-based learning, within classrooms and beyond school walls.

Whether you work in an urban or rural school, the two great interdependent facets of the universe are around you, open to your exploration with students: the natural world in which your city or town is embedded, and the world of human history and constructions. The first invites study through biology, astronomy, geology, and geography. The second engages the social sciences, urban planning, engineering, agriculture, and the fields of design. Ecology, philosophy, the arts, and spirituality bind these dimensions of place together. Just by venturing beyond the school and encountering the surrounding world, natural and social, through study and service, students position themselves as agents in their community, involved with others in action for the common good.

The resources featured here begin with publications and websites for place-based education—an umbrella term for all learning about environments that children can encounter and study directly. The second section addresses citizen science, when children focus on observing, investigating, and sharing discoveries about the natural environment in service to the wider scientific community. In addition to material in print and online, do not forget resources in the form of local advisors and experts, such as people in local history societies, environmental organizations, city agencies, and colleges or universities. Studying the world beyond classroom walls and bringing questions and reflection back into the classroom supports diverse approaches to learning: through all five senses, practical skills, and social engagement, as well as through all subjects in the curriculum.

Place-Based Education

The heart of this approach is connecting people to the place where they live in a spirit of community with their human, built, and natural world. According to definitions in resources featured here, place-based education is:

> . . . the pedagogy of community, the reintegration of the individual into her home-ground and the restoration of essential links between a person and her place. (Laurie Lane-Zucker, The Orion Society, foreword to *Place-Based Education* by David Sobel, iii)

> . . . learning that is rooted in what is local—the unique history, environment, culture, economy, literature, and art of a particular place. (*Rural Policy Matters* cited in *Place and Community-Based Education in Schools* by Gregory Smith and David Sobel, 23)

> . . . the process of using the local community and environment as a starting point to teach concepts in language arts, mathematics, social studies, science, and other subjects across the curriculum. (David Sobel, *Place-Based Education*, 7)

Place-based education overlaps with environmental education, civic education, project-based learning, experiential learning, and service learning, within the boundaries that it focuses these approaches on the local environment and community (Anderson).

The environment that students explore is their own town, city, natural surroundings, or region, and this is the focus of their projects and direct experiences. They learn civics by engaging with local processes of governance, and they direct their service to improving their community while learning about the conditions that have shaped it. As the resources that follow demonstrate, place-based education applies to any age, from preschool through high school and into adulthood, and it can be centered in schools or other local organizations. Invariably, it involves building partnerships with other institutions and community members.

Place-based education overlaps with environmental education, civic education, project-based learning, experiential learning, and service learning, within the boundaries that it focuses these approaches on the local environment and community.

The resources listed here do not attempt to be comprehensive. This selection emphasizes practical material about how to plan, implement, and sustain place-based projects, rather than academic discussions about pedagogical theory or studies of project outcomes—though a number of the items listed here will lead you into these literatures. It aims to adhere to work that focuses on place-based education rather than related fields such as environmental education, education for sustainability,

outdoor education, forest kindergartens, schoolyard greening, nature study, and service learning. Yet given the way that these fields are connected in practice, many of the resources on this list will introduce you to these related topics.

Place-Based Education Resources

Books

Anderson, Sarah K. *Bringing School to Life.* Lanham, MD: Rowman and Littlefield, 2017.

Anderson is the Field and Place-Based Education Coordinator at the Cottonwood School of Civics and Science, a K-8 charter school in Portland Public Schools, whose mission is to provide "authentic, hands-on learning experiences that are closely tied to the community." After she introduces place-based education, she describes its application to single subjects—such as mapping, history, science, and civics—as well as curriculum integration and partnership building. Each chapter closes with a list of further resources.

Beames, Simon, Peter Higgins, and Robbie Nicol. *Learning Outside the Classroom: Theory and Guidelines for Practice.* London: Routledge, 2012.

This text for teachers provides a basic background for understanding and implementing outdoor learning rather than specific activities. It discusses how to use the outdoors to learn across the curriculum, encourage student curiosity, and enable students to take responsibility, while investigating local landscapes and possibilities for sustainable development. It also covers partnerships, risk management, and supervising classes outdoors. The final chapter suggests how to prepare an action plan to move learning beyond the classroom.

Braund, Martin and Michael Reiss, editors. *Learning Science Outside the Classroom.* London: RoutledgeFalmer, 2004.

This collection of 14 chapters covers everything from developing the school grounds as an outdoor classroom; to making optimal use of field trips to destinations like zoos, museums, and industrial sites; to "reading" specific subjects like chemistry and physics in the surroundings; to practicalities like safety, learning assessment, and supplementing field studies with homework on the computer. Chapters close with resources for further reading.

Buxton, Cory A. and Provenzo, Eugene F. Provenzo, Jr. *Place-Based Science Teaching and Learning: 40 Activities for K-8 Classrooms.* Los Angeles: Sage, 2012.

This book begins with a history of place-based education and makes a case for the value of place-based science. It presents directions for 40 activities for studying science in school and neighborhood surroundings and engaging with the community, such as interviewing local scientists, visiting a water treatment plant, and conducting a wildlife census in a neighborhood park. These individual activities can be integrated into larger interdisciplinary projects.

Comber, Barbara. *Literacy, Place, and Pedagogies of Possibility.* New York: Routledge, 2016.

Written from an Australian perspective, this book focuses on place-based writing and filmmaking with children from multicultural backgrounds and environments of disadvantage. Its extended descriptions of work in primary and secondary schools are full of practical examples and resources, and situated in theories about the importance of grounding pedagogy in place.

Demarest, Amy B. ***Place-Based Curriculum Design: Exceeding Standards through Local Investigations.*** **New York: Routledge, 2015.**

This basic book for K-12 teachers is full of practical guidance and examples about how to organize curriculum and assessment around topics that matter to students personally and to their communities. It traces the decisions teachers make as they plan and implement curriculum based on local investigations. The conclusion discusses how school leadership can support teachers and whole schools to move toward learning in community contexts.

Derr, Victoria, Louise Chawla, and Mara Mintzer. ***Placemaking with Children and Youth: Participatory Practices for Planning Sustainable Communities.*** **New York: New Village Press, 2018.**

This manual for engaging children and teens in the participatory planning and design of parks and other public places can help initiate a single project or create sustained partnerships with city agencies or other community organizations that value young people's creativity and ideas. It is framed by chapters that discuss the significance of this approach to civic learning and how to evaluate and celebrate achievements. At its heart are chapters that present many methods for studying local communities, envisioning new possibilities, and working collaboratively with others for change.

Gruenewald, David A. and Gregory A. Smith. ***Place-Based Education in the Global Age: Local Diversity.*** **London: Lawrence Erlbaum, 2007.**

This collection features many leaders in place-based education, whose work crosses disciplines and student ages. In addition to foundational ideas, it presents accounts of place-based approaches, some at the scale of single classrooms and others involving whole schools and school systems. This is a book for readers who want to dive deeply into the theory and practice of place-based initiatives.

Haas, Toni and Paul Nachtigal. ***Place Value.*** **Charleston, WV: ERIC Clearinghouse on Rural Education and Small Schools, 1998.**

This small book begins with five short essays that develop its premise that, "Living well depends on the connections people have with one another and their surroundings." The essays propose how education can encourage a sense of place, sense of civic involvement, sense of worth, sense of connection, and sense of belonging. They are followed by annotated bibliographies of books that will take readers deeper into each essay's theme.

Harrington, Sheila (Ed.). ***Giving the Land a Voice: Mapping Our Home Places.*** **Salt Spring Island, BC: Land Trust Alliance of British Columbia, 1999.**

Out-of-print now, but still available, this classic on bioregional mapping shows how to integrate information about local plants, animals, landforms, watersheds, and human cultures, often as a tool for taking action to protect important landmarks, species, and places. Along with technical information and resources for map creation, it presents many beautiful examples, primarily at a level for the upper elementary and high school years and above.

Hart, Roger A. ***Children's Participation: The Theory and Practice of Involving Young Citizens in Community Development and Environmental Care.*** **London: Earthscan Publications, 1997.**

This book documents the potential of children and young adolescents to make valuable contributions to the monitoring and care of their local environments through examples from around the world that demonstrate their creativity, agency, and competence. It distinguishes adult-led actions from adult support for young people's capabilities. It reviews different models for engaging young people, in and out of school, and provides clear directions for a variety of methods that involve children and adolescents in evaluating their local environments, envisioning improvements, and managing and communicating change.

Krishnaswami, Uma. ***Beyond the Field Trip: Teaching and Learning in Public Places.*** **North Haven, CT: Linnet Professional Publications, 2002.**

The author is a writer-in-residence at a national monument, but her suggestions for weaving together writing, art, history, science, and math extend to parks, museums, and historic sites across the country and to all ages from early childhood through high school, as well as children with special needs. She shows how to make optimal use of class visits through advance preparation, active exploration on site, and support for the questions and inspiration that students bring back to the classroom.

Leslie, Claire Walker, John Tallmadge, and Tom Wessels. ***Into the Field.*** **Great Barrington, MA: The Orion Society, Nature Literacy Series, no. 3, 1998.**

This small book that can be easily taken into the field condenses the experience of three expert teachers: Tallmadge on writing in response to place, using a variety of exercises that encourage observation and interpretation; Leslie on nature journaling through annotated drawings; and Wessels on observing and interpreting clues to a landscape's history. Each section closes with a list of other resources. Although most examples are drawn from undergraduate teaching, they can be readily adapted to high school and grade school.

Pickering, Stephen (Ed.). ***Teaching Outdoors Creatively.*** **London: Routledge, 2017.**

This book reflects two concurrent movements in primary school education in the United Kingdom: one to encourage creativity in teaching and learning, and one to promote learning outside the classroom. Teachers and teacher educators discuss the use of local environments, fieldwork, "streetwork" that investigates the construction and design of streets and buildings, "storying" the outdoors through storytelling and play, adventure expeditions, and schoolwork in forests, beaches, and riverbanks. Chapters contain basic principles, many illustrations, activity boxes, and examples of school practices.

Renshaw, Peter and Ron Tooth. ***Diverse Pedagogies of Place*****. London: Routledge, 2018.**

This book describes the place-responsive teaching that evolved at six environmental education centers that serve schools across Queensland, Australia. Unified by a common history and freedom to experiment, each center represents a distinctive way to express core teaching values: embodiment and sensing a place, "storying" relationships to places, and uncovering contested stories across the history of a place. The book's reflections and practical experience can apply to any site, and the network of shared learning among the six centers forms a model for any region.

Smith, Gregory A. and David Sobel. ***Place- and Community-Based Education in Schools.*** **New York, Routledge, 2010.**

This book by two leaders of place-based education research and practice begins by putting persuasive arguments and information into the hands of anyone who wants to advocate for place-based education in their community. It reviews historical antecedents of this approach and suggests that it can address critical issues in contemporary education, then summarizes research that documents impacts on students' academic achievement and social, civic, and environmental learning, as well as impacts on teachers and communities. Several chapters feature inspiring examples of place-based projects.

Sobel, David. ***Mapmaking with Children: Sense of Place Education for the Elementary Years.*** **Portsmouth, NH: Heinemann, 1998.**

This is a basic guide to exploring local places, as well as places in children's literature, with ages five to twelve by creating maps and three-dimensional models. Each section comes to life with illustrations and accounts of children's work. Sobel shows how mapping and model-making can be ways to understand geography, biology, botany, and history and form emotional bonds with a place.

Sobel, David. ***Place-Based Education: Connecting Classrooms and Communities.*** **Great Barrington, MA: The Orion Society, Nature Literacy Series No. 4, 2005.**

This book condenses the author's lifetime of experience spent mentoring teachers in place-based approaches. After explaining place-based principles and concepts, Sobel briefly reviews research on outcomes. At the heart of the book are strategies for creating place-based schools. Descriptions of model projects show how the book's principles can be put into action.

Umphrey, Michael L. ***The Power of Community-Centered Education: Teaching as a Craft of Place.*** **Lanham, MD: Rowman and Littlefield Education, 2007.**

This extended case study of the Montana Heritage Project that was carried out in partnership with the Library of Congress, written by its director of many years, reflects deeply on core values of education. Its accounts of projects across the state primarily involve English and history, but the processes that the students follow, and the relationships with their communities that they develop, have relevance for every subject in the curriculum. A concluding chapter describes "Eight Practices of Community-Centered Teaching."

Vascellaro, Salvatore. ***Out of the Classroom and Into the World: Learning from Field Trips, Educating from Experience, and Unlocking the Potential of Our Students and Teachers.*** **New York: The New Press, 2011.**

The author, a professor at the Bank Street College of Education in New York, follows teachers as they lead their classes into extended explorations of present life, history, and possibility in the city. The subjects they investigate include slavery, immigration, Native American history, and bridge building. The book closes with a history of teacher education at the college in preparation for teaching through the environment, inspired by quests for the elements of a more democratic society.

Waite, Sue (Ed.). ***Children Learning Outside the Classroom: From Birth to Eleven.*** **London: Sage Publications, 2011.**

After an opening chapter that guides teachers in identifying places for learning outside the classroom, their meaning for students and the community, and opportunities that they afford, this edited collection contains 14 chapters about place-based principles and practices in preschools and primary schools. Some consider the basics of learning outdoors and in the community, while others focus on different parts of the curriculum and how to structure and manage outdoor learning. Ideas are illustrated with project activities and many vignettes of children outside.

Journals, Magazines, and Articles

Clearing – www.clearingmagazine.org

An online magazine that shares best practices in interdisciplinary place-based learning for all ages with the aim of increasing environmental literacy and skills to build a healthy and sustainable future. Rooted in the Pacific Northwest but relevant beyond this region, it features articles on topics like field studies, environmental service learning, community partnerships, and transforming schoolyards into sites for outdoor learning. Back issues and selected papers are available from the year 1998.

Community Works Journal – www.communityworksjournal.org

The online journal of the Community Works Institute (see below under Websites). Selected current articles on place-based service learning for grades K-16 are available as free downloads. Further reading and access to back issues requires an individual or institutional subscription.

Children, Youth and Environments – special issue on "Place-Based Education Theory and Pedagogy," vol. 21, no. 1 (2011), guest edited by Robert Barratt and Elisabeth Barratt Hacking

A large special issue that includes research articles, "Reports from the Field" that focus on lessons learned from practice, an annotated resource list, and reviews and notices about relevant books and films. Contributions span the United States and Europe, and cover different curriculum areas in primary schools through high schools.

Green Teacher – special issue on "Place-Based Education: A Toolkit for the 21st Century," vol. 110 (2016, Summer), guest edited by Amy Demarest

Articles by teachers for teachers full of inspiration and practical advice, such as how to conduct community explorations, build a green house, uncover "hidden stories" in your community, investigate a zoning issue, and cultivate stewardship for a local place. A subscription provides access to current and back issues as well as webinars.

Kahn, David and Laurie Ewert-Krocker. "Pedagogy of Place: Becoming Erdkinder," _The NAMTA Journal vol. 25, no. 1_ (2000, Winter): 145-167.

This article describes the beginning of the Hershey Montessori Farm School in Huntsburg, Ohio, an experiment to realize Maria Montessori's ideas for a land-based education for adolescents. Written by the project director and head teacher, it discusses the importance of experiences rooted in a particular natural and human-built place and the occupations that the farm affords for meaningful work that challenges the students' minds and bodies as they expand farm operations and contribute to the larger community. It connects the many occupations involved in developing and maintaining the farm to different areas of study, from practical skills to the liberal arts, math, and sciences.

Ludick, Pat. "The Pedagogy of Place," _The NAMTA Journal_ vol. 26, no. 3 (2001, Summer): 155-173.

This article is part of a special issue on "The Montessori Adolescent: Analysis in Retrospect" that contains many articles on *Erdkinder* experiments in the United States and reprints three lectures by Maria Montessori on adolescent education. The author draws on her experiences at the Hershey Montessori Farm School in Huntsburg, Ohio, as she shares reflections on the power of place in the lives of adolescents. The study of place connects them to the land, historic sites, ethnic neighborhoods, and metropolitan centers, where they may have transformational encounters with people, living and dead. Ludick outlines an integrated place-based curriculum that can be adapted to any location and she identifies the skills that it fosters.

The NAMTA Bulletin: March 2018 – www.montessori-namta.org/PDF/March2018Bulletin.pdf

Maria Montessori's vision of land-based learning for adolescents, or *Erdkinder*, remains a radical form of place-based education, where adolescents learn about a boundaried place and take responsibility for maintaining it as a productive economic, ecological, and social community. In this special issue, David Kahn traces the history of *Erdkinder* discussions and experiments in the United States. Several authors describe the urban land program for adolescents at St. Catherine's Montessori School in Houston. Louise Chawla closes the issue with a review of changes in the lives of rural and urban children across the twentieth century, which challenges rural-urban dichotomies and suggests that supportive environments for young people bring nature, culture, and commerce together.

Online Reports

Clark, Delia. ***Learning to Make Choices for the Future: Connecting Public Lands, Schools, and Communities through Place-Based Learning and Civic Engagement.*** **Woodstock, VT: Center for Place-Based Education and Community Engagement/A Forest for Every Classroom, 2008 –** www.nps.gov/civicresources/Learning to Make Choices.pdf

A manual for teachers, park rangers, interpreters, and other community members for engaging students in place-based education and civic engagement. After an introduction to place-based learning and its principles and benefits, the manual covers the nuts and bolts of launching and sustaining a place-based and civic engagement program, building partnerships, teacher development, and evaluation. Appendices include a list of resources, exercises for community building, worksheets, activities for mapping and exploring local landscapes, and brief descriptions of 50 exemplary projects.

Knapp, Clifford. ***Just Beyond the Classroom: Community Adventures for Interdisciplinary Learning.*** **Charleston, WV: ERIC Clearinghouse for Rural Education and Small Schools. ERIC document #388485 –** https://eric.ed.gov/?id=ED388485

Targeted for students in grades 4 through 9 but adaptable to lower or higher levels, this book is organized around twelve themes for local exploration and interdisciplinary learning. It is filled with ideas for inquiry, outcomes, activities, reflection, and performance assessments.

Rural School and Community Trust. ***Learning in Place.*** **Washington, DC: Rural School and Community Trust, 2000. ERIC document #58051 –** https://eric.ed.gov/?id=ED458051

Prepared by the Harvard Graduate School of Education for the Rural School and Community Trust, this report articulates the value of using landscape, family, and community surroundings as foundations for learning. Detailed descriptions of place-based learning in various Rural Trust elementary schools and high schools include helpful suggestions for getting started and sample curriculum materials.

Smith, Gregory A. "Place-Based Education." Oxford Research Encyclopedias online, 2017 – oxfordre.com/education/view/10.1093/acrefore/9780190264093.001.0001/acrefore-9780190264093-e-95

An online overview of place-based education, its historical antecedents, initiatives in the United States and other regions of the world, and obstacles and possibilities that it faces. It concludes with a list of material for further reading.

Films

The documentary filmmaker Bob Gliner focuses on telling the stories of initiatives that strengthen participatory democracy and just social and environmental change. His website, docmakeronline.com, includes film descriptions, trailers, and links to order DVDs or streaming video. Four of his films feature place-based education, showcasing inspiring models that other schools can follow:

Communities as Classrooms, 2016 (29 mins.)

In four schools in El Salvador, students build interdisciplinary curricula around solving problems in their communities, after determining the problems that they want to address. The film follows these processes week by week, offering models that can be applied in the United States and other countries.

Growing Up Green, 2014 (28 mins.)

A profile of a statewide program in Michigan, the Great Lakes Stewardship Initiative, that involves students in both rural and urban schools in projects to improve their local environments.

***Schools that Change Communities*, 2013 (58 mins.)**

Features public schools across the United States that use neighborhoods and communities as classrooms and engage students in significant and innovative community service.

***Lessons from the Real World*, 2011 (57 mins.)**

Stories of place-based education in elementary and secondary schools in Portland, Oregon, that show students engaged in cross-curriculum investigations of a nearby wetland, multicultural gardens, neighborhood history, transportation choices, and school beautification, as well as learning respect and care for people from all backgrounds and races.

Websites

Community Works Institute – www.communityworksinstitute.org

An institute that encourages place-based service learning through projects that bring schools and communities together. It provides professional development for K–16 educators in the United States and internationally, publications, and other resources that disseminate information about successful programs. Publications on their website include the *Community Works Journal* (see above), workbooks for curriculum development and assessment, and a collection of videos that feature the stories of teachers, school administrators, and service learning directors.

Discovering Place – www.umflint.edu/outreach/discovering-place

A program of the Office of Outreach of the University of Michigan-Flint, dedicated to supporting school-community partnerships that enable children and youth to identify and address environmental and social needs in their communities. The site offers a blog, case studies, and a series of seven free videos that cover topics like place-based principles, partnership building, methods, and assessment.

Photo by Stephen Cardinale for Growing Up Boulder.

Midway through their investigation of a local creek, these girls pause to greet some ducks. Their school project combined a study of the creek and adjoining park with civic engagement to contribute their ideas to city plans for park improvements.

Getting Smart – www.gettingsmart.com/categories/series/place-based-education

The site of a learning design firm that works with schools and other learning organizations and offers services that include place-based education. The site includes blogs on place-based education principles and school examples, podcasts, an infographic, and three reports: "Quick Start Guide to Place-Based Education," "Quick Start Guide to Place-Based Professional Learning," and "What Is Place-Based Education and Why Does It Matter?"

Our Curriculum Matters – www.ourcurriculummatters.com

This website was created by Amy Demarest, author of *Place-Based Curriculum Design* (see above). It includes a section on place-based education, the "big questions" it encourages, a model curriculum for learning about a lake and its water basin, and an extensive list of additional resources.

Promise of Place – www.promiseofplace.org

A collection of place-based education resources for teachers and school administrators offered by the Center for Place-Based Learning and Community Engagement in New England. It includes an overview of place-based education and answers to frequently asked questions, links to organizations that support place-based initiatives and teacher development, tools for evaluating project processes and outcomes, sample reports, and brief descriptions of many school projects.

Shelburne Farms – www.shelburnefarms.org/our-work/resources

In addition to on-site programs, this working farm, forest, and National Historic Landmark offers many free downloadable resources for educators. Material includes teacher-written case studies of nature and community-based learning in elementary schools and high schools, guides to establishing farm to school programs, the books *Cultivating Joy and Wonder: Educating for Sustainability in Early Childhood through Nature, Food, and Community* and *Healthy Neighborhoods/Healthy Kids*, and a handbook for interdisciplinary learning about the Lake Champlain Basin which can be adapted to other water features. All of these resources are filled with activities and teacher tips.

Citizen Science

Citizen science is a unique form of place-based education in that it engages children in real-world scientific inquiry beyond the confines of the classroom and as true naturalists. By definition, citizen science "empowers people from all walks of life to participate in the scientific process" (Havens and Henderson). Participants make observations, collect data, and collaborate with professional scientists to answer large-scale research questions. Through citizen science, children can strengthen their sense of place, connection to nature, and understanding of ecology, all while contributing meaningful data to the wider scientific community (Harris and Ballard).

Although the term was coined as recently as 1996, citizen science has been contributing to our study of the natural world for centuries. Some of the first evidence of this practice dates back to the ninth century in Japan, when citizens tracked the timing of peak cherry blossoms in preparation for their annual festivals. More recently, but before the professionalization of science, early naturalists such as Carolus Linnaeus and Henry David Thoreau were among the first practitioners of citizen science with their extensive observations of plants and animals. Then, in 1900, the National Audubon Society launched its inaugural Christmas Bird Count, perhaps the earliest example of organized data collection by a group of amateur naturalists (Miller-Rushing). Today, citizen science programs operate all over the world, enlisting millions of participants and thousands of collaborating organizations. These programs cover an array of ecological topics and often cater to educators and children with simple protocols and easy-to-use equipment.

Citizen science takes advantage of crowdsourcing to collect a far greater volume of data across time and space than individual scientists could possibly collect on their own. One of the many reasons for its success at such a large scale is the use of technology for instantaneous data entry anywhere in the world. However, if technology in the classroom is a concern, there are alternatives. For example, children could send a hard copy of the data to the program headquarters by regular mail, or an adult (e.g., teacher, local expert) could upload the data on the children's behalf.

The following list of active citizen science programs and resources is by no means exhaustive. Many of the programs are international or national, but regional and local programs are also ubiquitous in communities. Many local nature centers, forest preserves, botanic gardens, zoos, and environmental organizations offer citizen science and place-based experiential learning opportunities. In addition, contact local representatives for the Nature Conservancy, Department of Natural Resources (DNR), Sierra Club, National Audubon Society, or National Wildlife Federation, all of which can provide information about local, regional, national, and international programs.

Citizen Science Programs

Birds

Audubon Christmas Bird Count – www.audubon.org/conservation/science/christmas-bird-count

The National Audubon Society has hosted a Christmas Bird Count (CBC) every year since 1900, making it the largest and longest-running citizen science project in the world. This project was created by ornithologist Frank Chapman who proposed a bird census as an alternative to the reigning tradition of Christmas "side hunts" (during these hunts, hundreds of birds were killed in a single game). Each year from mid-December through the first week of January, tens of thousands of volunteers participate in the count, and a sizeable amount of data is generated from their efforts; in one year alone (118th CBC, 2017–2018), over 59 million individual birds were reported. With this expansive, long-term dataset, scientists can detect changes in bird populations over time and space and make informed conservation decisions. The Great Backyard Bird Count (http://gbbc.birdcount.org/) is a similar bird census held every February.

eBird – www.ebird.org/home

eBird is an online platform for birders of any experience level to report bird sightings in their communities. Users can upload lists of the birds they spot, along with the location and time of day, as well as photos and audio recordings (if available) as evidence of their findings. eBird also offers a portal for communication with other avian enthusiasts, including regional experts and scientists. eBird was created by the Cornell Lab of Ornithology in 2002, but since its inception, the project has expanded significantly to include hundreds of collaborating organizations. Today, eBird boasts "more than 100 million bird sightings contributed each year by eBirders around the world," making it one of the largest biodiversity citizen science projects in existence.

Celebrate Urban Birds – www.celebrateurbanbirds.org

Celebrate Urban Birds (CUBs) is another Cornell Lab of Ornithology creation, but more targeted to urban and underserved communities, particularly participants without science experience. One aspect of the CUBs mission is to maintain green spaces for birds amid heavily trafficked urban environments. In service of this goal, the organization offers "mini-grants" to support community engagement in birding and environmental stewardship. Data from participants is submitted using bilingual (English and Spanish) "kits," which include instructions for how to participate, a bird identification guide, and data sheets. Their website features species maps and downloadable data, along with other resources for children and teachers (e.g., art, garden, and science project ideas).

NestWatch – www.nestwatch.org

The goal of this project is to track the reproductive biology of birds (e.g., timing of nesting, number of eggs laid, hatchling survivability, etc.) and learn about nest behaviors. The procedure and requirements for participation are more rigorous than most citizen science projects for a variety of safety reasons (to protect both the birds and the data collectors; see their "Code of Conduct" page for details). Therefore, this project is catered to the seasoned citizen scientist and all children must be accompanied by an adult. NestWatch recently released a "Thinking Outside the (Nest) Box" educational resource for teachers, which may spark some ideas for additional work in and out of the classroom.

FeederWatch – www.feederwatch.org

A sister of NestWatch, FeederWatch takes advantage of an activity beloved by many homeowners and school communities. From November to April, participants are invited to count and survey the birds visiting their feeders in service of tracking winter bird populations.

HawkWatch International – www.hawkwatch.org

HawkCount – www.hawkcount.org

Although two separate entities, HawkWatch International (HWI) and HawkCount are close partners and share data in an effort to track and quantify migrations of diurnal raptors (e.g., hawks, vultures, falcons, eagles). Like most citizen science programs, HWI generates an annual project report with summary statistics from that calendar year and also within the context of broader trends. HWI's website provides Raptor ID Fact Sheets and a list of their migration sites for ideal bird watching. HWI schedules several hawk-watching field trips and identification programs throughout the year for adults and children of all experience levels.

Avian Conservation Center: Center for Birds of Prey – www.thecenterforbirdsofprey.org

In addition to the more general programs mentioned above, there are also countless organizations interested in the conservation of one particular bird species. For example, the Avian Conservation Center, based in South Carolina, has rallied behind the Swallow-tailed Kite, whose populations have been declining in the southeastern United States. The Center is enlisting the help of citizen scientists to track population levels by asking one simple question: "Have you seen this bird?" Very often this type of data is taken into consideration when a species is recommended for federal or state listing (as threatened or endangered). If you would like to contribute to the preservation of a bird species, it is just a matter of finding a project that is appropriate for your region.

Insects/Pollinators

Monarch Watch – www.monarchwatch.org

The famous monarch butterfly migration from Mexico to the United States and Canada is the topic of interest for this large-scale citizen science program. The Monarch Watch Tagging Program uses a mark and recapture method to answer questions about changes in migration patterns, mortality along the way, distance traveled, etc. To participate, citizen scientists are given uniquely-coded tags that are then attached to the underside of the butterfly's hindwings (tags come with detailed instructions to ensure the butterflies are not harmed in this process). Along with placing the tag, participants are asked to report the date, geographic location, and gender of each tagged butterfly. The Monarch Watch website also features information about rearing Monarchs, butterfly gardening, and monarch biology, as well as a "Milkweed Market" for ordering milkweed.

Journey North – www.journeynorth.org

Journey North is a professed "easy entry point to citizen science." This organization works very closely with children, teachers, schools, and nature centers across the United States, Canada, and Mexico to track wildlife migrations and seasonal weather patterns. Although tracking monarch butterflies is one of their larger projects, Journey North also follows hummingbirds, songbirds, earthworms, frogs, and leaf emergence. Consequently, there are many ways to volunteer and contribute data to this organization in a meaningful way. Once collected, the data is quickly turned into easy-to-use, interactive maps for visualizing trends.

Monarch Larvae Monitoring Project – www.mlmp.org

Whereas the above-mentioned citizen science projects are more focused on monarch migration patterns, the Monarch Larvae Monitoring Project (MLMP) is studying their breeding biology. As an MLMP volunteer, you monitor a stand of milkweed plants regularly and record evidence of monarch larvae, aphids, and other indicators. This might be an ideal activity for a group of children to do together at a nearby stand of milkweed, as it offers an exciting opportunity for repetition and care of an outdoor environment. Peruse the MLMP website to get suggestions for choosing monitoring sites, a list of supplies needed, strategies for improving data accuracy, and other monitoring tips.

Great Sunflower Project – www.greatsunflower.org

In response to the pollinator crisis, the Great Sunflower Project enlists volunteers to count pollinator visitors in their yards, parks, gardens, or while on walks/hikes. The level of involvement could be as active as searching a large section of a prairie for pollinators, or as casual as noting when a hummingbird flies by your window. To standardize that variation, the website offers instructions for stationary counts, traveling counts, area counts, and casual observation. Their website also features bee identification guides, book recommendations, resources for educators, and other materials. The Great Sunflower Project earned its name because historically, volunteers monitored Lemon Queen Sunflowers, which are widely available in stores, easy to grow, and commonly visited by bees and birds.

Caterpillars Count! – www.caterpillarscount.unc.edu

Caterpillars Count! is a citizen science project for measuring arthropod abundance on trees and shrubs. For accurate results, participants are encouraged, but not required, to take an online quiz until they reach a score of at least 9/10 consistently. During the quiz, they are shown an image of an arthropod and asked to pick one of many categories (e.g., bees and wasps, flies, butterflies and moths, beetles, caterpillars, true bugs, spiders, aphids, grasshoppers). People can take the quiz as many times as they like because the pictures change each time. The website also provides a printable arthropod ID guide to take into the field. Caterpillars Count! uses the data to answer several research questions related to arthropod foliage preferences and the relationship between caterpillar emergence and the breeding season for birds.

Lost Ladybug Project – www.lostladybug.org

This project appeals to young children for a number of reasons. Ladybugs are found all over the world in many different patterns and colors. The Lost Ladybug Project (LLP) asks participants to celebrate that diversity by submitting photos of ladybugs in their neighborhood. Children might enjoy counting the spots on each ladybug's wings and using one of the LLP guides to identify them to species. There is growing concern about the dwindling number of native ladybugs in North America, so this activity is both fun for children and important for insect conservation. In fact, the data collected for this project has contributed to several publications in scientific journals (see "LLP Research and Publications" section on their website).

Xerces Society – www.xerces.org/citizen-science

Although not a citizen science program in and of itself, the Xerces Society is worth mentioning here because it has founded several of its own projects. The website provided here links to projects for tracking bumble bees, dragonflies, and Monarch butterflies. It also lists a number of other insect citizen science programs, some of which were already mentioned. The Xerces Society is an international nonprofit organization that is active in research, advocacy, and policy initiatives for the protection of threatened, endangered, and at-risk invertebrates.

Plants

Project Budburst – https://budburst.org/

Budburst is a product of the Chicago Botanic Garden, but its reach is far wider. Citizen scientists record the timing of plant life cycle events (e.g., leafing, flowering, and fruiting), also known as phenology, or the "science of appearance." To participate, simply choose a plant (there is a list of 300 plants on their website if you need ideas) and follow the instructions for either a "life-cycle observation" or a "one-time observation." The former necessitates going back to the same plant over a period of time to record all its life cycle events, whereas the latter is a snapshot in time: an observation of a single plant on one particular day, in one particular location, and in one moment of its cycle. For educators, the Budburst directors have included ideas and activities for integrating this project into K-4, 5-8, 9-12, and higher education classrooms. (Note: Nature's Notebook, www.usanpn.org/natures_notebook, is a similar program from the National Phenology Network.)

Plants of Concern – www.plantsofconcern.org

The Plants of Concern (POC) program is a rare plant monitoring program for the Chicago Wilderness Region (areas of Illinois, Indiana, Wisconsin, and Michigan). As such, the protocols and requirements for participation are more stringent. Given the sensitivity of rare plant populations and, in most cases, confidentiality required to monitor them, POC hosts training workshops in the spring for new volunteers at the Chicago Botanic Garden. After the required training, volunteers are assigned a site and expected to visit that site once a year during the plant's bloom time. As a POC volunteer, you are also considered a Chicago Botanic Garden volunteer, which comes with several admission perks. Officially, children need to be 15 to volunteer at CBG, but POC "has worked with younger interns on a case-by-case basis."

Wild Spotter – www.wildspotter.org

Wild Spotter takes advantage of crowdsourcing to "help find, map, and prevent invasive species in America's wilderness areas, wild rivers, and other natural areas." As they walk, hikers can download the Wild Spotter app and upload evidence of invasive plants in their local National Forests and National Grasslands. Invasive plants are opportunistic, which means they are often found in disturbed areas with heavy foot traffic, such as along trail edges. So that technology is not the focus of this project, perhaps children can identify and assess the invasive plants and the adults can upload the data. Wild Spotter collaborates with the USDA Forest Service so participants are encouraged to reach out to Forest Rangers and other experts at the preserves prior to volunteering.

Other Wildlife

iNaturalist – www.iNaturalist.org

iNaturalist began as a master's project at the University of California Berkeley and is now one of the leading biodiversity citizen science programs in the world. Its mission is to connect people to nature, as well as to other naturalists. The data iNaturalist collects is not feeding into a specific scientific study, but is instead free to be used by anyone. At its core, iNaturalist is an enormous repository of open data. Anyone is welcome to submit observations of any living organism. If you are unable to identify your submission, very often other volunteers or scientists will reach out and help you solve the mystery. To further encourage collaboration and communication, participants can create "projects that allow you to pool your observations with others. "Herps of Southern Africa" and "California Oaks" are two examples of active projects.

Keeping Track - www.keepingtrack.org

Sue Morse founded Keeping Track in 1994 because she believed there was value in tracking wildlife, not only to monitor population levels, but also to gauge ecosystem health more generally. As top predators in the food chain, mammals such as wolves, bears, and bobcats are considered by many in the scientific community to be keystone species, which means their removal affects change in lower trophic levels. Therefore, learning to identify tracks and other signs from these important animals can help conservationists preserve their dwindling habitats. Their "stories [are] written in the snow, the sand, and the mud" (Sue Morse, Plenary Address at the 2015 Northeast Natural History Conference). Participating in this citizen science project could be a suitable outdoor winter activity for children.

FrogWatch USA – www.aza.org/frogwatch

FrogWatch USA, created by the Association of Zoos and Aquariums (AZA), is a "bioblitz" (short-term, biological surveying) event in the spring and summer. This is a nighttime activity for those with a keen ear. Volunteers are asked to listen to and discern the calls of frogs and toads in wetland environments and report what they hear. Amphibians are proving to be one of the most vulnerable groups to habitat loss and disease, so AZA is very active in amphibian conservation.

Yellowstone Wolf: Project Citizen Science – www.yellowstonewolf.org/index.php

Here again is an example of a specialized project for one particular animal, and there are many more like it. The reintroduction of wolves to Yellowstone National Park is one of the greatest conservation success stories in history. However, scientists still have unanswered questions about predator-prey interactions, pack dynamics, and the prevalence of disease (specifically sarcoptic mange) in the park. Thus, this project asks visitors to submit photos and other data if they happen to see a wolf(ves) during their visit. From these photos, scientists can quantify pack size or spot mange lesions, for example.

Abiotic

EarthEcho Water Challenge – www.worldwatermonitoringday.org

The EarthEcho Water Challenge engages citizens around the world in an effort to protect water resources and monitor local waterbodies. As it stands now, EarthEcho has more than 1.5 million participants from nearly 150 countries and data from over 70,000 bodies of water. Kits for testing turbidity, temperature, dissolved oxygen, and pH are available for purchase. Once tested, EarthEcho encourages its participants to use that data as a springboard for taking action to improve water quality and health. "Levels of action can range from visual surveys, to litter pick-ups, to one-time habitat improvement projects."

GLOBE Clouds– www.globe.gov/web/s-cool/home

GLOBE, or the Global Learning and Observations to Benefit the Environment Program, is principally sponsored by NASA, with additional support from the National Science Foundation (NSF) and the National Oceanic and Atmospheric Association (NOAA). GLOBE manages a number of worldwide Earth science projects, one of which analyzes the role clouds play in shaping the Earth's climate. Although satellites tell us a lot about cloud formation from above, NASA scientists also need information from an earthly perspective to get the entire picture. This is where citizen scientists come in. Volunteers begin the process by finding their satellite "overpass time" (i.e., when a satellite is passing over a given location) and then submitting cloud data to the NASA Langley Research Center. The next step is to wait for NASA to compare your observations to the corresponding satellite data, at which point you will receive an email with the results. The GLOBE website has a wealth of educational resources related to Earth science and links to many other projects.

Galaxy Zoo – www.zooniverse.org/projects/zookeeper/galaxy-zoo

Galaxy Zoo is one of many Zooniverse "people-powered research projects." Zooniverse is a collaboration between institutions from the United Kingdom and the United States and the creator of several physics, climate, and space-related projects. However, Zooniverse's approach to citizen science is a bit different than most; in this case, scientists already have the data they need in the form of telescope images or historic documents, and they need volunteers to classify and analyze them. For example, Galaxy Zoo aims to classify galaxies from millions of images taken by a telescope stationed in Chile. Users will see an image from that telescope on the computer and be asked to characterize that galaxy (e.g., spiral, elliptical, irregular). Perhaps these images can be printed so children can do this work without looking at a screen. Of note, a field guide can be clicked open at any time during the classification process without losing your work if a refresher is needed.

Globe at Night – www.globeatnight.org

Globe at Night measures light pollution, or the excessive collection of artificial light, most often an issue in dense, urban areas. Light pollution hides the stars and planets of the night sky behind a veil of hazy, orange-yellow light, which can confuse migrating nocturnal animals or interfere with astronomical research. To help Globe at Night quantify light pollution globally, you can submit a classification of your night sky based on the number of stars/constellations you are able to see. Globe at Night provides printable images of common constellations to look for, which might be a fun night-time activity in and of itself.

Community Collaborative Rain, Hail, and Snow Network – www.cocorahs.org

CoCoRaHS was created in 1998 in response to a devastating flash flood in Fort Collins, Colorado the year before. A dedicated group of people wanted to develop a program to better predict and map intense storms using citizen science, so CoCoRaHS was born. The program requires participants to obtain standardized gauges for measuring precipitation and snow, which can either be purchased or potentially borrowed from your local area project coordinator (there are several in each state). Participants can look through the CoCoRaHS "Training Slide-Shows" to learn where to place the gauge outside (e.g., height above ground and distance from trees). This organization receives an average of 10,000 daily reports from areas all over the United States, Canada, and the Bahamas and each report is immediately visible online.

Citizen Science Resources

Books

Burns, Loree Griffin. *Citizen Scientist: Be a Part of Scientific Discovery from Your Own Backyard.* New York: Henry Holt and Company, 2012.

This book appeals to children and teachers as both an introduction to citizen science and guide to many of the most popular youth-focused projects, complete with photographs of children in action. Burns emphasizes how easy it is to walk outside of your house or school and join reputable scientists.

Cooper, Caren. *Citizen Science: How Ordinary People Are Changing the Face of Discovery.* New York: Overlook Press, 2016.

This book is a must-read for those who want to learn more about the power and value of citizen science. In three parts, Cooper describes several ongoing projects, discusses how technology has transformed the practice of citizen science, and champions the work of ordinary citizens in some of the most famous conservation stories.

Dickinson, Janis L. and Rick Bonney, editors. *Citizen Science: Public Participation in Environmental Research.* Ithaca, New York: Cornell University Press, 2012.

Janis Dickinson is a professor of natural resources and former Arthur A. Allen Director of Citizen Science at the Cornell Lab of Ornithology. Rick Bonney is the director of the Department of Program Development and Evaluation in the same Cornell lab. As two well-known names in the field, they have created a useful resource that shares their insights on implementing a successful citizen science project. The book includes suggestions for project design, data management, and other logistics.

Forrester, Anna. *Bat Count: A Citizen Science Story.* Mount Pleasant, SC: Arbordale Publishing, 2017.

Bat Count is Anna Forrester's "fic-informational story" about a young girl who is inspired to count bats each night and send her numbers to scientists. This children's book "introduces the empowering practice of citizen science with a story of action, reassurance, and hope" (www.annaforrester.com/books). Bat Count was named the 2018 Outstanding Science Trade Book for Students K–12 by the National Science Teachers Association and the Children's Book Council, along with several other accolades.

Articles

Bonney, Rick, et al. "Next Steps for Citizen Science." *Science vol. 343, no. 6178* (2014): 1436–1437.

Published in *Science,* a premier scientific journal, this article discusses citizen science's enormous potential as a data source and offers suggestions for reaching that potential.

Dickinson, Janis L., et al. "The Current State of Citizen Science as a Tool for Ecological Research and Public Engagement." *Frontiers in Ecology and the Environment* vol. 10, no. 6 (2012): 291–297.

This article considers citizen science's invaluable contribution to ecology and conservation. The authors write, "Citizen science, with its 'many eyes', is an effective way to find rare organisms, track invasions, and detect boom-and-bust events" (293). The article includes a table of online resources that can be used to find current citizen science projects.

Harris, Emily and Heidi Ballard. "Real Science in the Palm of Your Hand: A Framework for Designing and Facilitating Citizen Science in the Classroom." *Science and Children* 55 (2018): 31–37.

Harris and Ballard use the Lost Ladybug Project (LLP, described in this article) as an example for engaging children in the scientific process. The authors explain how the LLP helped children develop expertise, contribute data, draw conclusions, and share their findings with the community.

Havens, Kayri and Sandra Henderson. "Citizen Science Takes Root." *American Scientist* vol. 101, no. 5 (2013): 378–385.

Written by a senior scientist and Director of Plant Science and Conservation at the Chicago Botanic Garden (CBG), alongside the Director of Citizen Science at the National Ecological Observatory Network (NEON); this is a highly cited publication. It provides a timeline of the history of citizen science as a discipline and introduces Project Budburst, a CBG program supported by a "nation of flower watchers."

Shah, Harsh R. and Luis R. Martinez. "Current Approaches in Implementing Citizen Science in the Classroom." *Journal of Microbiology and Biology Education* vol. 17, no. 1 (2016): 17–22.

As the title suggests, this article is focused on citizen science's role as an educational tool for developing critical thinking and scientific literacy among children. It includes a table of well-known citizen science projects for elementary, middle, and high school levels.

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THE (MISSING) POLITICS IN ENVIRONMENTAL AND SUSTAINABILITY EDUCATION

David W. Orr *is the Paul Sears Distinguished Professor of Environmental Studies and Politics Emeritus and senior advisor to the president of Oberlin College. He is a founding editor of the journal* Solutions *and the founder of the Oberlin Project. The Oberlin Project was formed out of David Orr's vision of full-spectrum sustainability: an all-encompassing joint venture by the town and college to create a thriving, sustainable, and environmentally friendly community in Oberlin, OH. Orr is the author of eight books, including* Dangerous Years: Climate Change, the Long Emergency, and the Way Forward *(Yale, 2016) and* Down to the Wire: Confronting Climate Collapse *(Oxford, 2009), and coeditor of three others. He has authored over 200 articles, reviews, book chapters, and professional publications. He has been awarded eight honorary degrees and a dozen other awards including a Lyndhurst Prize, a National Achievement Award from the National Wildlife Federation, and a Visionary Leadership Award from Second Nature. His career as a scholar, teacher, writer, speaker, and entrepreneur spans fields as diverse as environment and politics, environmental education, campus greening, green building, ecological design, and climate change.*

THE (MISSING) POLITICS IN ENVIRONMENTAL AND SUSTAINABILITY EDUCATION

by David W. Orr

David Orr suggests that environmentalist and peace educators must teach civics, law, government, and political history to deeply cultivate an understanding of the influences and policies that create and perpetuate environmental destruction and humanitarian crises. Citizens, especially students, must comprehend the political forces and the public interests that have created the current destabilization of our environment and human community and must become civically and politically engaged to affect actual policy change.

"It's very hard to see us fixing the climate until we fix our democracy." — James Hansen

For all of our successes, and they are many, and for all of our considerable efforts, and they are admirable, humankind is losing the effort to save a decently habitable planet. The immediate causes include rapid climate destabilization, ocean acidification, and the loss of biodiversity that are all driven by the expanding human footprint. With determination and effort, some damage is repairable in a timescale that matters, but much of it is irreversible. As much as one wishes it were otherwise, it is not.

The reflections below are to my colleagues in environmental and sustainability education who as Aldo Leopold wrote, "live alone in a world of wounds . . . that believes itself well and does not want to be told otherwise" (165). Since those words were written in the 1940s, we have done many good things, but in total they do not match the scope, scale, and urgency of the challenges we presently face and that our progeny will confront through the centuries of the "long emergency." There are many reasons for this, beginning with the massive size and duration of the "environmental problem." But most important is our tendency to overlook the inconvenient reality that the use and disposition of land, air, water, forests, oceans, minerals, energy, and atmosphere are inevitably political, having to do with "who gets what, when and how." With notable exceptions, however, we avoided politics and giving offense in a highly polarized time, but now things are fast coming undone and time for correction is very short. To wit.

If today is a typical day in our nation's capital, the dismantling of the Environmental Protection Agency and our collective capacity to protect our air, water, lands, biota, climate, and health will proceed apace, but mostly out of sight. Our common heritage of lands, parks, national monuments, and unique ecosystems will decline further. Today the interests of the wealthiest 1% will advance while those of the bottom 90% will recede. Today the causes of peace and justice will languish, those of militarism and violence will expand. No inspiring truth or ideal will be forthcoming from the White House to dilute the rampant greed, lies, megalomania, and criminality that infect our politics, now more than ever in our history. Suffering will be imposed on the most vulnerable citizens with cold indifference; our duties and obligations to prevent future suffering and injustice will be ignored in silence. Painstakingly assembled over two centuries, the institutions and norms of democratic governance will be further debased behind closed doors. Our common wealth is up for sale; a tsunami of lies and "dark" money threatens to drown what remains of the public interest.

None of this is particularly new and none of it is accidental. It is rather the result of decades of effort to reshape the American political system to the advantage of corporations and the wealthy. To do that, it was necessary to undermine venerable institutions and subvert our public language and our common understanding of facts and reality. Not to put too fine a point on recent history, it was a decades-long coup but without tanks in the streets or colonels with dark glasses. How did it happen?

I

One answer is that we were not paying attention when we might have helped to move our politics in a better direction. While we were writing brilliant articles and books, they were taking over school boards and city councils. While we were holding great conferences in beautiful places, they were taking over state legislatures and governors' offices. While we were doing science, they were doing the politics of taking over Congress, the Senate, the court system, and learning the arts of manipulation by television, radio, internet, and social media. While we were growing school gardens and talking about exciting possibilities for renewable energy and ecological agriculture, they were steadily forcing our politics to the right and taking over the party of Lincoln, Teddy Roosevelt, and Eisenhower. While we were getting in touch with our inner selves, they were staffing up on K Street. While we were trying to make peace with capitalism, they were at Davos advancing the cause of neoliberalism and working to make the rich much richer and the poor that much poorer. While we were trying to be bipartisan, they were doing zero-sum politics, that is to say heads they win, tails we lose. While we were most often right about the issues, they were taking power. While we were trying to be reasonable, they were cultivating and exploiting resentment. While we were reading Aldo Leopold and Rachel Carson, they were marinating in the bizarre philosophy of Ayn Rand. And, perhaps most important, while we were doing our eco-thing, Richmond attorney and future Supreme Court Justice Lewis Powell was drafting the memo to the US Chamber of Commerce (1971) that became the battle plan for a massive corporate counter attack against environmentalism and progressive movements. In the fevered politics of those turbulent years, his memo sparked creation of the organizations charged with legitimizing and justifying the politics of a new era of robber barons.

Who are they? Whatever else they may be, they are not conservatives in the mold of Edmund Burke or Richard Weaver or even Barry Goldwater. Many are descendants of the far-right of American politics, with roots in the South with its long history of opposition to the Federal government as a countervailing force to systems of racial discrimination and unbridled corporate power. Their agenda includes a hodge-podge of ideas such as "getting government off our backs" (but leaving predatory corporations there), ending Social Security, further enlarging the military, terminating a woman's right to control her own body, eliminating environmental protections, defunding social programs, ending restrictions on gun ownership, freedom from public obligations, and always more tax cuts for corporations and the wealthy. In other words, they don't like government regulations, taxes, assertive women and minorities, national forests, public parks, the Postal Service, science, fact-checkers, the media, controls on gun ownership, and, of course, "liberals." They include neo-Nazis, white supremacists, internet trolls, Tea Partiers, climate change deniers, extreme evangelicals, FOX News true believers, Limbaugh "ditto-heads," Ayn Rand libertarians, free market ideologues, and some well-heeled people who really ought to know better. Disproportionately, they're angry white guys, and their enablers aren't as angry but are adept opportunists who know how to make money from those who are. They are well armed, noisy, and increasingly well organized. They are inclined to the kind of self-righteousness that justifies means by the unquestioned self-anointed holiness of the ends. They now control what remains of the Republican party that once stood for the kind of conservatism that included a commitment to fiscal integrity, personal probity, a regard for facts, public decency, balanced budgets, common sense, and the kind of patriotism that could cost you something. Donald Trump gave voice to their inchoate rage and created a world-class model of a *kakistocracy*, an ancient Greek word that means government run by the worst, least qualified, and most unscrupulous. They are a minority but an intense, highly organized, and well-funded minority and sometimes that is all it takes to cause political havoc. On the eve of the Nazi takeover in 1933, for example, only 22% of Germans were members of the Nazi Party.

"We," on the other hand, are mostly Democrats, liberals, and self-described progressives dispersed across multiple overlapping issues. We don't like polarization or hardball politics, or say we don't. We like to "get to yes" and cost-free "win-win" solutions. We listen to National Public Radio, get our news from MSNBC and *The New York Times*. We read publications like *The New Yorker* and *The New York Review of Books*. We have college degrees. We are geographically confined to reservations in the Northeast and West Coast and a few urban enclaves and college towns in between. We are more likely to live in cities and work in professions. We talk at length about listening to "them" with greater empathy, feeling their pain, understanding where they're coming from, etc. Too often, we are analytical, boring, and long-winded. We talk in footnotes and are a poor match for those who recite well-rehearsed talking points delivered early each morning by a disciplined media machine.

Nonetheless, we can be very proud of the intellectual capital and knowledge we progressive environmentalists built over many decades. We wrote remarkably good books on environmental education, sustainability, justice, environmental economics, renewable energy, climate change, sustainable agriculture, and greening cities. Our analysis of complex policy issues was, by and large, very good. In a rational country, we would be winning in a landslide. Alas, history and human nature are seldom so simple. The spoils go to the winners, not always to those who were merely right about the issues. "They" now hold the power that runs the country and is running it into the ground. They control the weapons that could destroy civilization. They control policies affecting taxation and spending, healthcare, regulation, banks, the distribution of wealth, education, public health, military spending, war and peace, media, law enforcement, and the environment that are destroying the foundations of democracy. And for the most part, they are proudly ignorant of ecology and Earth systems science.

This is a slight caricature, but only slightly. The line separating "us" from "them" is admittedly blurry and so I will qualify my words. Sometimes people change their opinions, reason breaks through the fog of ideology, and sinners repent. Sometimes it is possible to find the holy grail of common ground, and there are conversions on the road to Damascus. Sometimes people backslide to a more reasonable place, but mostly people cling to their opinions and narratives like shipwrecked sailors clinging to flotsam on the high seas.

On the other side, some of us have worked on political campaigns and have taken on issues like climate change, but our hearts are in building green schools, designing cool cities, and creating models of a future with organic gardens and regenerative farms. All good and necessary things. We aimed to be decent and accommodating, while mostly avoiding the hard work of long-term political organizing, persuasion down at the truck stop, local politics, and the messy issues of governance and politics. In other words, we did the uncontroversial bottom-up things, but they seized the commanding heights of power and wealth.

II

The dominant fact of our time is the rapid decline in the vital signs of Earth and the growing possibility of "cascading system failures threatening basic necessities like food supply and electricity" and much more (Sengupta; Steffen et al.). For educators the question is what we can do to seriously and soon improve the human prospect, not just lament our peril. The overriding fact is that we know much more about the science of ecology than we do about the implications it poses for governance, law, and policy. As a result, we do not yet know how to translate ecology and Earth systems science into laws, regulations, public institutions, and economic arrangements with the resilience and durability necessary for human survival over the long haul. The upshot is that any adequate response to our predicament must begin with an understanding of political economy large enough to include ecology and Earth systems science and the organizational capacity to make it mainstream. (Perhaps like the Mont Pèlerin Society formed by Frederick Hayek, Milton Friedman, and others in advancing the cause of neoliberalism in the decades after World War II, only better thought out, much faster, and more inclusive. See Mirowski & Dieter Plehwe; Burgin.)

As noted above, all environmental and sustainability issues, from local to global, are unavoidably political, having to do with "who gets what, when and how." The "who" includes all of those qualified as citizens, including those unborn but presently excluded from our moral community. "What" includes everything taken from nature that is transformed into wealth and the ecological processes that recycle the resulting waste or consign it to land, oceans, and atmosphere. The "how" of politics are the rules that govern inclusion, exclusion, political processes, and the allocation of power. For citizens there is no way to be apolitical. To the extent that we stand aloof from politics, we give tacit assent to the forces that are destroying the habitability of the Earth. For educators the conclusion is straightforward: Politics, policy, and political philosophy should feature in the core of environmental and sustainability education. Otherwise, we leave our students clueless, inarticulate, and adrift in the political turmoil that is engulfing the world and impairing our common future. We do not have an environmental crisis as much as a political crisis that is the sum total of our failures of foresight, empathy, and morality in the conduct of our public business. It is, however, an open question what kind of political changes will be necessary to calibrate human institutions and behavior with the Earth's systems and processes in a manner that advances the causes of justice, fairness, decency, and the hard-won gains of civilization. Whatever arrangements we make, however, we must reckon with five fundamentally political challenges.

For educators the conclusion is straightforward: Politics, policy, and political philosophy should feature in the core of environmental and sustainability education. Otherwise, we leave our students clueless, inarticulate, and adrift in the political turmoil that is engulfing the world and impairing our common future. We do not have an environmental crisis as much as a political crisis that is the sum total of our failures of foresight, empathy, and morality in the conduct of our public business.

The first and most mundane has to do with governance. The emergence of environmental law and regulation in the years from 1969 to 1980 presaged the dawn of a new beginning between humankind and the natural world. The signal accomplishments included the passage of the National Environmental Policy Act (1969), creation of the Council on Environmental Quality, the Clean Air Act, the Clean Water Act, the Wilderness Protection Act, the Endangered Species Act, the Scenic and the Wild Rivers Act, and by executive order, formation of the Environmental Protection Agency. These achievements reflected a consensus among Democrats and Republicans that created the legal foundation for present-day environmental policy that is now under assault by the Trump administration.

As important as they were, however, environmental laws and regulations of that era left much undone. They did not confront larger issues such as climate change, energy policy, land use, technological change, and the overall scale of the economy that were in various ways left to the market. As a result, the goal to grow the economy on one hand conflicts with protecting the environment on the other. The Environmental Protection Agency, however, still has no "organic statute" to resolve those competing ends and to clarify its mission and set priorities. The abolition of the Office of Technology Assessment in 1994 crippled the federal capacity to foresee technological problems, which is equivalent to turning the headlights off on a dark night while traveling at a high rate of speed on a winding road. Environmental regulation, such as it is, occurs under the commerce clause of the Constitution—an awkward arrangement at best. Moreover, deeper issues having to do with the recalibration of governance with the holistic and long-term ecological systems that require foresight and a systems thinking were left unresolved in the ongoing conflict between public and private rights. It is not clear whether or how a democratic society might resolve such issues.

The second challenge, then, has to do with the viability of democracy. We simply do not know whether democracy as practiced today will rise to the challenge of protecting and restoring the ecosphere.[1] Biologist Garrett Hardin had his doubts. In a famous essay in *Science* (1968), he wrote that the only way to avoid tragedy in the use of common property resources was "mutual coercion, mutually agreed upon." Economist Robert Heilbroner in *An Inquiry into the Human Prospect* (1974) arrived at the same conclusion, writing, "I not only predict but I prescribe a centralization of power as the only means by which our threatened and dangerous civilization will make way for its successor" (175).

[1] The future of democracy has always been in question. Among its critics, Plato regarded it a prelude to tyranny. Aristotle was not much more sanguine. The founding fathers of our Republic were wary of it. John Adams believed that democracies always end by committing suicide. James Madison believed that, with luck, democracy in America might last a century. English writer E. M. Forster could give it only two cheers, H. L. Mencken none at all, believing people incorrigibly stupid. Economist Joseph Schumpeter likewise thought voters became dumber when they entered the political arena. Robert Dahl, perhaps the greatest student of democracy in the twentieth century once described himself as a "pessimist" about its future. Winston Churchill captured our predicament in his often-quoted obsevation that democracy was the worst form of government except for all the others ever tried. In short, democracy is everywhere and always a wager that enough people would know enough and care enough and be wise enough to participate honorably and well in the conduct of the public business.

In 1977, political scientist William Ophuls argued, as did the authors of *The Limits to Growth* (1972), that the capacity of Earth to supply resources and process our wastes is constrained by what he called "ecological scarcity," by which he meant the sum total of all environmental limits. From that perspective, he drew conclusions about politics and governance similar to those of Hardin and Heilbroner. "Democracy as we know it," he wrote, "cannot conceivably survive [because] ecological scarcity . . . engender(s) overwhelming pressures toward political systems that are frankly authoritarian" (Ophuls 200, 216). The problem of democracy is the incompatibility of the freedom "to behave in a selfish, greedy, and quarrelsome fashion" and the imperative to discipline our appetites in order to avoid ecological scarcity. The epigraph to his book, taken from a letter written by Edmund Burke in 1791, summarizes our predicament:

> men are qualified for civil liberty in exact proportion to their disposition to put moral chains upon their own appetites . . . society cannot exist unless a controlling power upon will and appetite be placed somewhere, and the less of it there is within, the more there must be without . . . men of intemperate minds cannot be free. Their passions forge their fetters.

Burke's conservatism required a kind of forbearance alien to citizens in mass consumption societies conditioned to be dependable and dependent consumers yearning for more. Well-conditioned consumers, however, are not likely to go quietly and willingly into the night of ecological frugality and self-denial.

The third challenge is posed by the inevitable limits to the growth economy. The fact is that we have never been as rich as we assumed because we off-loaded costs and risks on others in some distant place or on future generations in the form of resource scarcity, toxicity, biotic impoverishment, climate instability, conflict, poverty, disease, and wrecked lives. The extractive industries have been highly profitable mostly to the extent they did not pay the full costs for the damage they inflicted. The larger point is that, sooner or later, the laws of entropy will bring economic growth to an end. We cannot know exactly how it will occur or whether it will occur by choice or by necessity, but we do know that when it does, it will threaten social stability in direct proportion to the inequality of distribution and the accumulation of past grievances. We could pretend otherwise as long as enough people believed the myth that a rising tide would lift their particular boat. When the economy shudders to a halt and the belief in the miracle of endless economic growth vanishes, however, inequality will drive resentment, things will come undone, and the pitchforks will come out.

Unless, that is, technological developments allow us to make an end run around ecological scarcity and keep the party going, which raises a fourth challenge. The core idea is that technological breakthroughs create jobs, surmount ecological limits, cycle all wastes back into "food," and otherwise allow us to ignore growing income disparities. Salvation by superior gadgetry and better design requires no messy politics and unsolvable dilemmas, only problems solvable with more research and smarter policy. Technology, however, has its own unanticipated effects and sometimes "bites back." It arrives usually as wonders and miracles; only later do we discover a darker side. Smart phones, for example, useful for communicating and providing access to information, also surveil, manipulate, and addict. Starting as idealistic enterprises aiming to "do no evil," companies such as Facebook, Amazon, and Google morphed into something wholly different, dedicated to moving fast and breaking things, devil and internet trolls take the hindmost. The idealism of founders gives way to profit-making, the temptations of power, and the unanticipated effects of complex systems operating in the dark beyond a manageable scale. If we have a philosophy of technology, it is more akin to cheerleading or just resignation to the inevitable, than to critical thinking and careful public policy. Our students, notably those from STEM programs, often graduate as technological fundamentalists unable to ask basic questions such as "what else does it do?" The fact is that we do not buy a technology, but rather we buy into a larger system of which a particular device is only a small part. The larger system that sells us smart phones and automobiles alike includes their extractive industries, production facilities, history of exploitation and pollution, effects on human health and social cohesion, land use, politics, lobbyists, political power, biodiversity, and so forth. We stand at the threshold of "super-intelligence" and robots that will be vastly more intelligent than humans and in ways that we will not comprehend. Regardless, robots are being deployed to battlefields and to domestic police departments with consequences that at best are troubling. The advent of a dangerous new era is coming without much public discussion or awareness of the perils ahead. In the latter category, it is entirely possible that we will be displaced by artificial intelligence in some form or other. If so, they or it may consider us as rather stupid, disposable inconvenience.

A fifth challenge is the obvious need to expand our reach to applied professional fields such as engineering, medicine, business, finance, economics, and law, not as curricular add-ons but as a fundamental rethinking of applied disciplines in light of what is known about ecological interdependence. Much of what presently passes for professional education results in what Robert Jackall describes as "an ethos of organized irresponsibility and recklessness that has become the disquieting hallmark of our times" (240; see also Schmidt, particularly his description of the "radical professional," 265–280). The result is a narrowing gap between licensed professional behavior and ecological mischief that undermines the long-term prospects for humanity. The cure, among other things, will require us to ask larger and harder questions that lie beyond conventional paradigms, disciplines, and modes of thought pervasive in higher education.

III

Sitting quietly in the ruins of the Nazi Party rally grounds in Nuremburg, Germany, one can almost hear the echoes of Adolf Hitler's carefully staged harangues and the responding shouts of 100,000 followers who were about to be fed into the slaughterhouse of World War II. It all seems so distant and yet so current. How did the pastoral Germany of Kant and Goethe descend to that of Hitler and Himmler? How did great universities and scientific institutions succumb so easily to Nazism? Where was the resistance, particularly from churches, unions, and civic organizations? The transformation happened quickly (mostly between 1928 and 1934) nearly eighty years ago and the infection has not died out yet.

Erika Mann, in *School for Barbarians* (1938) identified education as the key to the process by which the mind and language of a nation was subverted. "The Führer's best bet lay," she wrote, "from the very beginning, in the inexperience and easy credulity of youth. It was his ambition, as it must be any dictator's, to take possession of that most fertile field for dictators: the country's youth . . . All the power of the regime—all its cunning, its entire machine of propaganda and discipline—is directed to emphasize the program for German children" (19–20). The deflection of the mind and loyalties of a nation cannot be quickly undone. In the midst of the ruins of 1945 as the war was ending, historian and philologist, Victor Klemperer, described an encounter with a former student of his who said, "I still believe in HIM (Hitler), I really do" (122).

Our situation differs from that in Germany in the decades from the 1920s to 1945, but there are similarities as well. Yale historian Timothy Snyder argues, for example, that Hitler's drive for *lebensraum* (i.e. land and resources) in Eastern Europe was an early version of the geopolitics of ecological scarcity and so a warning to us. For the readers of this journal, it is worth pondering the role of education in an age of unprecedented ecological deterioration, climate destabilization, inequality, and collapsing democratic institutions. The political immune system necessary to counter ignorance, fanaticism, gullibility, fear, misogyny, racism, and violence begins early on in classrooms where the young learn the basics rules of democracy: critical thinking, honesty, fairness, empathy, non-violence, and citizenship. None of this comes easily or naturally. Youth must be educated to be citizens of a democracy and to know the costs of careless and indifferent citizenship. They must also learn to see themselves as citizens of the community of life. As citizens of a democracy, they must understand the intimate relationship between democracy, human rights, dignity, justice, peace, and the human prospect and so must become knowledgeable about history, politics, the law and the workings of government. As citizens in the ecological community, they must understand ecology, natural cycles, and the web of life. As dual citizens of human and natural communities they must learn the value of the wider community and the common good that joins the interests of both. They must understand the intimate and reciprocal relationship between politics and our ecological prospects.

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Further, like those of Germany in the 1930s, schools, colleges, and universities are under attack by those who would subvert their purposes and narrow the focus to those subjects and curricula useful for jobs and careers in a growth-oriented economy and so non-threatening to the power of banks, corporations, and oligarchy. We must resist the temptation to shrink our courses and curricula in order to avoid controversial subjects. We must continue to teach connection and connectedness between peoples, humans and nature, our past and our future.

Environmental and sustainability education, heretofore, has been about everything but the politics that got us into our predicament and might yet be the path out of it. Our education, generally, and that pertaining to the environment in particular has mostly excluded civics and the role of politics and governance in our predicament. Often we did so to avoid controversy and the charge of partisan bias. In doing so, however, we were also being political—in effect supporting the status quo and the forces that prefer a passive and ecologically illiterate public; consumers not citizens. Alas, there is no way to be apolitical or non-political. In Dietrich Bonhoeffer's words, there is no such thing as "cheap grace."

The upshot is this. The convergence of rapid climate destabilization and disintegrating democratic institutions is the historical context for our work as educators. I think it unlikely, as stated in the epigraph, that we will stabilize the climate without first repairing and strengthening democratic institutions. In both cases, as well as in other aspects of "the long emergency," the time for remedy is very short. Environmental and sustainability educators are, in effect, the first responders working with the rising generation to help guide the formation of their attitudes, capacities, loyalties, and affections. We should help them grow to become "radical professionals," people of irrepressible courage, creativity, joy, and humility dedicated to the causes of life, justice, truth, decency and democracy (Schmidt 265–280).

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MARIA MONTESSORI'S COSMIC STORIES AND CONTEMPORARY SCIENCE

Gerard Leonard *is an AMI trainer. He currently trains elementary teachers at the Montessori Training Center Northeast in Hartford, CT. He taught for over thirty years in primary, elementary, and adolescent Montessori programs. He has consulted for elementary Montessori programs both in the US and Mexico. He has given keynote addresses and workshops for NAMTA, AMI-USA, the Maria Montessori Institute, in London, UK, and Montessori Aotearoa New Zealand (MANZ). He was a co-developer with David Kahn of the "Guided by Nature" exhibit seen at the 2013 International Montessori Congress in Portland, OR and of the NAMTA centenary exhibit,* A Montessori Journey: 1907–2007.

MARIA MONTESSORI'S COSMIC STORIES AND CONTEMPORARY SCIENCE

by Gerard Leonard

Gerard Leonard uncovers the living organic vision of Montessori scientific thought principles to ponder for our generation of Montessori: "To be ecoliterate is to understand the basic principles of ecology and to endeavor to live by them. Having a systems view of life, or what we would call in Montessori education, 'an understanding of the interdependencies in the natural and man-made worlds and between these worlds,' provides the framework within which the human values of justice, compassion, love, beauty, and peacemaking can be examined."

This talk was presented at the NAMTA conference titled Montessori History: Searching for Evolutionary Scientific Truth *in Cleveland, OH, April 20–22, 2018.*

Maria Montessori devised Cosmic Education as "a universal syllabus"[1] for children ages six to twelve years. Her decades of experience with children of this age told her that they wanted to understand the workings of their universe and that their seemingly endless how and why questions about the world could only be approached if we centered the children in the story of our universe as a whole. She wrote that the new generations must apply themselves to this universal syllabus of studies where "all items of culture must be concerned as different aspects of the knowledge of the world and the cosmos."[2]

> …it is through a childhood modified and freed from the ties of unconsciousness, of weakness, of psychic deviations and of ignorance, that it is possible to act by giving a new form of intellectual culture and by cultivating new sentiments for humanity. It is this later part, culture, that which represents the study to be carried out in schools, the universal syllabus that can unite the mind and the consciousness of all men in one harmony, that we intend by Cosmic Education.[3]

Cosmic Education is based on what Dr. Montessori called the Cosmic Theory. The theory derives from the thinking of the great Italian geologist Antonio Stoppani.[4] Stoppani was one of the first geologists to look at life as an integral component of Earth's geological processes. He also described modern human activity (since industrialization) as "a new telluric force which in power and universality may be compared to the greater forces of nature."[5] He wrote in his book *Acqua ed Aria* of the role of corals, foraminiferans, crinoids, and many other life forms and their incessant work in both building our islands and continental landmasses, and of their central role in preserving the purity of our water and air.[6]

The atmospheric chemist Paul Crutzen has called Antonio Stoppani the father of biogeochemistry.[7] The field of biogeochemistry studies the great cycling of chemical elements on our planet via inter-related biological and geological processes. The cycling of carbon, nitrogen, and water, for example, have now become areas of major concern because of the accelerating effects of human interventions in these cycles on the atmosphere, hydrosphere, and lithosphere, and the implications of climatic change

1 Maria Montessori, *Cosmic Education*, Lecture, India, 1946 in *The Child, Society and the World,* Oxford: Clio, 1989, 111.
2 Ibid.
3 Ibid.
4 Ibid. 106; Maria Montessori, *From Childhood to Adolescence,* Kalakshetra, Madras (Chennai), India: Madras Press, 1973 ,48.
5 See: Will Steffen, Paul J. Crutzen, and John R. McNeill, "The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature?" *Ambio,* vol. 36, no. 8, 2007, 614–621.
6 Antonio Stoppani, Acqua ed Aria ossia la purezza del mare e dell'atmosfera, Milan: Hoepli, 1882.
7 Paul Crutzen was a co-recipient of the 1995 Nobel Prize in chemistry for work in atmospheric chemistry, particularly concerning the formation and decomposition of ozone.

[Montessori] believed that a tendency towards harmony and the maintenance of balance on the planet as a whole was an important factor in evolution. Today many scientists point to the fact that not only ecosystems but the Earth itself demonstrates tendencies towards self-organization and self-maintenance in order to consistently work towards a state of homeostasis.

on human habitation, energy sources, and food production, and on the entire biosphere.[8]

Dr. Maria Montessori's genius brought these cycles, through the study of the work of creatures both living and extinct, into the consciousness and the hearts of children via stories of what she called their "cosmic tasks." By this term she meant the work of these creatures as they transformed their environments by living and dying but seen from the vantage point of Earth's total balance (what Montessori also called Earth's household or the telluric economy). The work, on a global (or cosmic) scale, of the sun, water, air, carbon, and other inanimate elements is also presented to the minds of elementary children in a way in which they can imagine their vast effects and explore various aspects through experiments and going-out into the natural world. She believed that a tendency towards harmony and the maintenance of balance on the planet as a whole was an important factor in evolution. Today many scientists point to the fact that not only ecosystems but the Earth itself demonstrates tendencies towards self-organization and self-maintenance in order to consistently work towards a state of homeostasis.[9]

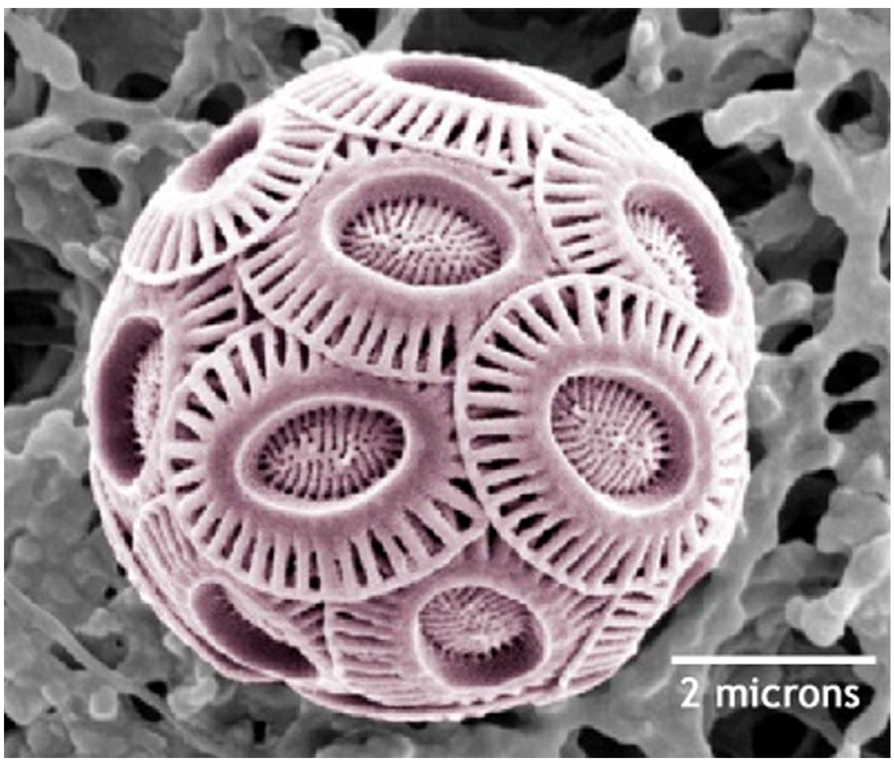

Image credit: Claudia Sprengel

Phytoplankton

Here is an example of a cosmic tale:

> Every early summer off the west coast of Ireland one can see from high up in space huge swirling turquoise patterns in the ocean below. These are made by a phytoplankton called *Emiliana huxleyi*. These little single-celled algae are only four thousandths of a millimeter in diameter and yet together they have been seen to cover an area of 100,000

8 William H. Schlesinger and Emily S. Bernhardt, *Biogeochemistry: An Analysis of Global Change*, Oxford: Academic Press, 2013.

9 Fritjof Capra and Pier Luigi Luisi, *The Systems View of Life*, Cambridge, UK: Cambridge University Press, 2014.

> square kilometers at this time of year. They are the "grass" of the ocean's food chain. The ocean blooms at this season with these little beauties because of nutrients that rise up from the sea floor. They shimmer and shine so beautifully because of their coccoliths, platelets made of calcium carbonate with gorgeous designs. We see their legacy in the cliffs of Antrim in Ireland and the famous white cliffs of Dover in England. The Irish naturalist Michael Viney has called these little beings "a shining star among organisms so vital to ocean life," but also, so vital "to the future of human comfort." What did he mean by this? Their photosynthesis generates oxygen both for the ocean water and for the atmosphere above. But these little fellows also help to balance our climate! "The shimmering armour that makes the blooms of coccolithophores so obvious reflects light and heat back into space rather than warming the ocean. One satellite study found an annual area of blooms covering 1.4 million square kilometers. And the algae's mass manufacture of coccoliths from calcium and carbon adds to the ocean's seabed store of carbon and affects the amount of carbon dioxide held in the atmosphere."[10]

The power of using such big numbers when describing the cosmic tasks of the very small is one method that Maria Montessori used extensively to fire the creative imaginations of elementary-aged children in order to help them visualize Earth systems on a global or cosmic scale, or to imagine the incredible networks of relationships one can observe under a microscope.

She wrote, "We can imagine how many there must be of those microscopic creatures that light up miles and miles of a tropic sea with phosphorescence, rivaling the stars on a clear night. In a single drop of water under the microscope one can detect hundreds of minute living things, what must be their number in the great ocean?"[11]

Montessori waxes lyrical about the work of the microscopic foraminiferans (the tiny zooplankton doing similar cosmic work to the coccolithophores) and she especially extols the work of the corals. The work of the corals, as exemplars of living beings performing a tireless work that for long ages have maintained the purity of our oceans, was extremely important to Maria Montessori. Her grave in Noordwijk in The Netherlands is surrounded by a necklace of corals. She used their role in the calcium carbonate cycle as a means of communicating a deep understanding of the great cycles of nature, and of the interdependencies within the biosphere. She wrote that to understand the nature of the work of such living beings in the cosmic order of things would also help us to better understand the work of children who similarly work tirelessly when given the freedom and the suitable environment needed to follow their natural tendencies.

Stories such as these are designed to inspire wonder and a sense of awe at the patterns, the order, and the harmonies that are revealed once one begins to look at the interrelatedness of things, whether on a grand scale or even on a small scale.

Dr. Montessori followed Stoppani in seeing humanity as a new geological force on the planet; such was the power of human beings to make changes on a scale only formerly seen in the work of enormous ice sheets or as a result of volcanic eruptions.[12] Antonio Stoppani had over a century ago come up with the term Anthropozoic Era to distinguish the uniqueness of the human presence in the Earth. Paul Crutzen is now well-known in the world of climate change studies for his delineation of the Anthropocene—a period beginning around 1800 with industrialization and the rapid growth of the use of fossil fuels.

> The term *Anthropocene* suggests that the Earth has now left its natural geological epoch, the present interglacial state called the *Holocene*. Human activities have become so pervasive and profound that they rival the great forces of Nature and are pushing the Earth into planetary 'terra incognita'. The Earth is rapidly moving into a less biologically diverse, less forested, much warmer, and probably wetter and stormier state.[13]

10 Michael Viney, "The Ocean Blooms," in *Reflections on Another Life,* Dublin: Irish Times Books, 2015.
11 Maria Montessori, *To Educate the Human Potential.* Madras (Chennai), India: Kalakshetra Press, 1973, 21.
12 See Maria Montessori, *Education and Peace,* Chicago: Henry Regnery, 25.
13 Steffen, Crutzen, and McNeill, "The Anthropocene," op. cit., 614.

In her book *From Childhood to Adolescence,* Maria Montessori noted that when elementary-aged children understood the workings of some of the great chemical cycles and the interrelationships, that an interest in research was activated and a natural philosophy was opened up in the enquiring minds of the children. In her concluding remarks she states:

> We have touched upon several cycles, as, for example, that of calcium carbonate. But all is interrelated. And what is interesting is to be able to orient ourselves among these correlations. To present detached notions is to bring confusion. We need to determine the bonds that exist between them. When the correlation among the notions, by now linked one to the other, has been established, the details may be found to tie together among themselves. The mind, then, is satisfied and the desire to go on with research is born.[14]

Research is a pivotal aspect of the human enterprise. Teilhard de Chardin speaks to this in his book *Building the Earth.*

> We must put in the forefront of our concrete preoccupations the systematic arrangement and exploration of our Universe, understood as the true country of Mankind…The time has come to realize that research is the highest human function.…[15]

It is quite extraordinary that Cosmic Education introduces children to the work of researching the intimate workings of their home planet. And this is primarily done through exploring in an all-inclusive manner that Montessori calls "the needs of growth and of life."[16] For example, the children's studies of the needs of the plant will include ventures into meteorology, hydrology, geology, biology, chemistry, and ultimately the cycles of biogeochemistry. This kind of research leads to ecological understanding.

We need human beings who are deeply connected to distant human beings and to other living beings and can see our planetary systems on a vast scale, that is, can overview large regions of the globe and also look into deep time. Dr. Montessori called this the development of "human solidarity in time and space" and pointed to this consciousness as a necessary element in "world reconstruction."[17]

> If we wish to bring to children knowledge of the real and material world, nothing can be more significant and accurate than the image of the tree that is human solidarity, rooted in a distant past and extending its branches towards eternity, while we live the infinitesimal second allotted to human life.[18]

In Cosmic Education we devote considerable time to stories and presentations, and experiments showing the work of water on a cosmic scale. The great hydrological cycle is presented in a way that integrates the cycling of calcium carbonate and the role of corals and other sea creatures in this work of planetary maintenance. An entire chapter in *From Childhood to Adolescence* is devoted to water. In this chapter Maria Montessori describes the work of life in the sea solving the cosmic problem of all the limestone carried to the sea by Earth's rivers.

From time immemorial, she writes, "there have been animals exercising this function…the task of seizing the excessive calcium carbonate and fixing it."[19]

Here is a story of water when viewed from a cosmic perspective:

> Water is very important. Water is found everywhere across our entire planet, as rivers and streams, as seas and oceans and lakes, as rain, as clouds, and as in the form of ice. Plants and animals drink water and many plants and animals and other kinds of living beings live in water. In fact, there is more life in the oceans than on land, and life began in the oceans many eons ago.

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14 Montessori, *From Childhood to Adolescence,* op. cit., 97.
15 Pierre Teilhard de Chardin, *Building the Earth,* https://www.teilharddechardin.nl/oud/Teilhard-Earth.pdf
16 Ibid, 97.
17 Maria Montessori, "Human Solidarity in Time and Space," *AMI Communications,* 2003/4.
18 Ibid., 20.
19 Montessori, F*rom Childhood to Adolescence,* op. cit., 50.

Look at the globe and observe how much of the surface area of our planet is covered by water. Some people think our planet should be called "planet water" rather than "planet Earth"! When astronomers look for signs of life on other planets, one of the first things they look for is evidence of the presence of water.

Our oceans are vast and deep. Our tallest mountains could be placed into the deepest parts of our oceans and their peaks would not come above the surface. And life exists from the surface right down to the deepest parts. The largest mammal that has ever lived, the blue whale, which weighs as much a twelve school busses and can reach 30 meters in length, can live comfortably in the oceans of our world. And the tiniest of shelled creatures, such as the microscopic foraminiferans live in vast quantities in our oceans and have done so for millions of years. These and many other creatures do their work day in and day out. They never rest.

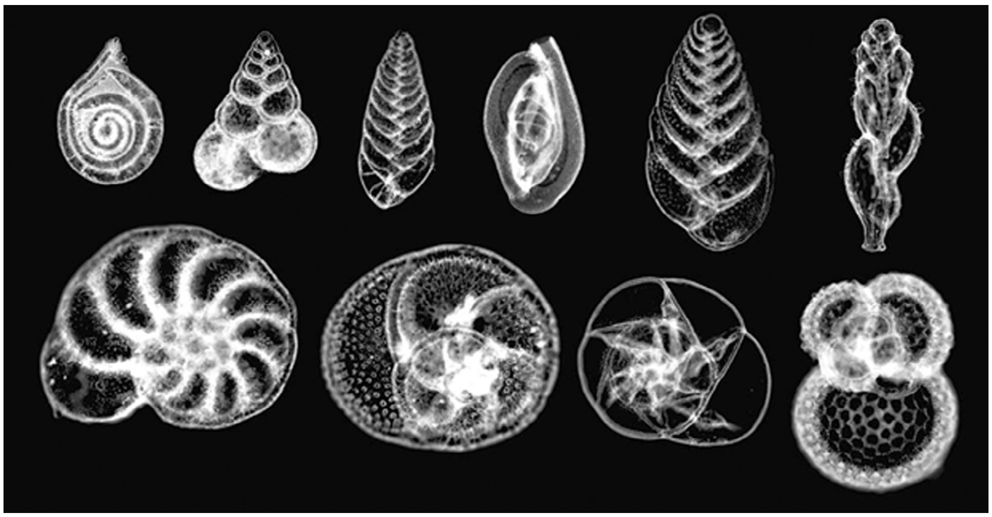

Image by GeologyCafe.com

Foraminiferans

Now, water has a very hearty appetite. Water's appetite is for rocks! When she falls as rain she combines with carbon dioxide gas in the atmosphere and forms a weak acid called carbonic acid. When the water then penetrates the Earth's rocks and flows as great rivers it carves the rocky surface and sculpts the landscape and even carves and sculpts underground in beautiful forms. Water is an artist! Water also carries enormous amounts of sediments to the sea. The sediments are deposited into the seas and oceans, and amazingly after thousands of years the sediments, which are so great they could build mountains many miles high, have not polluted the seas and oceans. That is because many living creatures doing their work of eating other creatures and plants have taken the sediments and built them into the hard parts of their bodies, into their shells for example, or into their exoskeletons. Scientists say that a very important substance in these sediments, called calcium carbonate or limestone, is being "buried" or "fixed" by these creatures. They are performing the task of keeping our water pure.

Enormous quantities of calcium carbonate have been carried to the oceans in solution and extracted by creatures such as foraminiferans, trilobites, sea lilies, mollusks, and the corals as they filter the ocean water. One little one-celled creature drinks as much water as if an adult human were to drink two cubic feet of water per second for a whole lifetime. So, such creatures work to purify huge volumes of water. They do something very important that we could not do. The corals have been doing this work for a long time. Let's look at our timeline of life and see when they began in the early Paleozoic Era. The corals and all kinds of shelled creatures have over millions of years built up islands and even huge mountains. Many mountains on Earth are mainly composed of the fossils of these marine creatures.

The corals need special conditions to do this work. They need ocean water of just the right temperature and they need the help of ocean currents, of tiny little algae that live

> on the coral, and of the many little shoals of fish they provide a home to, in order to stir the water in just the right way to bring their food and calcium carbonate in solution to them so they can continue to live and build their beautiful reefs. The Great Barrier Reef alone is the size of 25 states of Connecticut and is about 8,000 years old.[20]

This is part of the cosmic tale we tell about water and the calcium carbonate cycle.

Recent discoveries in biogeochemistry stress the tremendous importance of the calcium carbonate cycle, both the research into its evolutionary history and the research into its important role in the chemistry of the atmosphere and hydrosphere.

> …[the calcium carbonate cycle is] one of the most ancient biogeochemical cycles and one which reflects the profound geochemical and biological changes that have occurred as the Earth system has evolved through time.… [21]

> …biologically driven carbonate deposition provides a significant buffering of ocean chemistry and of atmospheric CO_2 in the modern system.[22]

Furthermore, we have now discovered that "the calcifying organisms that underpin the deep-sea carbonate sink are threatened by the continued atmospheric release of the fossil fuel CO_2 and increasing acidity of the surface ocean."[23]

It would appear that some 80 plus years after Dr. Montessori first wrote about the importance of calcium carbonate biogeochemical cycle[24] that its significance in our "universal syllabus," and in Cosmic Education, has not diminished but rather has become even more essential as we strive to better understand how to preserve the health of our water and air, of the coral reefs, and of the other calcifying creatures of our oceans. [25]

The fundamental idea of the cosmic theory of Stoppani promoted by Montessori is an integrated view of Earth's geology and biology, and the powerful geological scale effect of human life on the biosphere. This theory is increasingly being supported by the most recent studies in ecosystems science and biogeochemistry.

> …clearly, since the industrial revolution, humans have added more carbon dioxide to the atmosphere than the carbonate-silicate cycle or the ocean can absorb each year.[26]

> In the past 50 years, humans have changed the world's ecosystems more than in any other comparable period in human history.[27]

Maria Montessori understood that in order for children to construct themselves cognitively, ethically, and socially, they needed prepared environments and certain essential keys, so they could explore, order, name, and classify their world. For children under the age of six, she gave keys to the world in the form of sensorial materials. These "materialized abstractions" for color, size, length, weight, pitch, temperature, and so on are the keys for the child's mind to begin to classify their immediate natural and built environments. For children between six and twelve years old she said we should give the child keys to the universe. These keys have a sensorial basis but now the powerful creative imaginations and reasoning faculties of the minds of six- to twelve-year olds are also highly engaged in addition to the hands.

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20 Adapted from Montessori, *From Childhood to Adolescence*, op. cit., chapter on water.

21 Andy Ridgewell and Richard E. Zeebe, "The Role of the Global Carbonate Cycle in the Regulation and Evolution of the Earth System, *Earth and Planetary Science Letters,* vol. 234, no. 3–4 (2005), 300.

22 Ibid.

23 Ibid.

24 Maria Montessori, *Six Lectures on Cosmic Education*, 1935/36, London, in *AMI Communications* 2007–2009.

25 David Attenborough, *The Great Barrier Reef* (2015) and *The Blue Planet* (2001), BBC Films.

26 Schlesinger and Bernhardt, op. cit., 8.

27 Steffen, Crutzen, and McNeill, op.cit., 617.

One example of these keys are models for the elements hydrogen, oxygen, nitrogen, and carbon. These are given to the children as classic atomic representations each showing respectively, one, two, three, and four arms, thus indicating how they bond with other atoms to form molecules.[28] Montessori observed that it was through the process of exploring how the atoms of these elements combined (i.e., according to their valences) that the children's interest was aroused.

> The four elements we symbolize for the children in this way are, as it were, the key to the universe [H, O, N, C]. They are easy to remember because they have 1, 2, 3, and 4 lines. They do, in fact, make us think of keys. We could depict them in the form of bodies having arms capable of grasping one another… The way in which the elements unite is what maintains the attention of the child.[29]

For example, Montessori writes in considerable detail about how these elements are composed and decomposed in the "cycle of rocks" and of how the children become passionately interested to see what happens to the symbols in the various chemical reactions. She writes that the elements involved could be considered "as the keys that command the intimate movements of nature."[30]

"The four elements we symbolize for the children in this way are, as it were, the key to the universe." Maria Montessori

The choice of these four elements is interesting. They are still currently seen as the central elements involved in organic molecules, and carbon, hydrogen, and oxygen together with calcium and some others are important in many inorganic molecules.

Current microbiology, biogeochemistry, and other sciences attest to the importance of understanding the work of these four elements in Earth's laboratory. Two more elements have now been added to these four in order to complete the pantheon of major actors in the drama of life on Earth.

"Six elements, H, C, N, O, P, and S are the major constituents of living tissue and account for 95% of the mass of the biosphere."[31] This is how the current major text (2015) on biogeochemistry describes their relevance.

Of these six elements, Brian Swimme and Thomas Berry wrote in *The Universe Story:*

> Centuries of analysis have provided us with an unparalleled understanding of the role carbon plays. Besides carbon, life involves primarily, hydrogen, oxygen, nitrogen, sulfur and phosphorus. *To know this is to know something real and irreducible about the nature of life, something detailed, something essential*.[32] [author's emphasis]

28 Dr. Montessori gave these elements impressionistic colors that connect them to their roles in the great cycles: H- blue (for water H_2O), O- red (for combustion/energy), N-pink (for flesh, life, and the nitrogen cycle), C-black (for coal).

29 Montessori, *From Childhood to Adolescence*, op. cit., 72, 74.

30 Ibid., 77.

31 Schlesinger and Bernhardt, op.cit., 15.

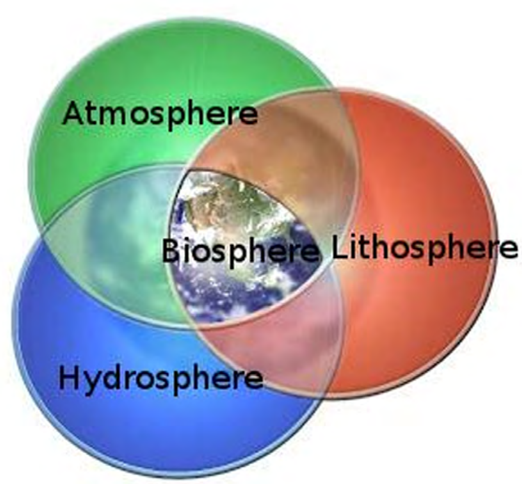
32 Brian Swimme and Thomas Berry, *The Universe Story*, 36-37.

Lynn Margulis wrote in her seminal book *Microcosmos*: "These six elements are now the chemical common denominator of all life, accounting for 99 percent of the dry weight of every living thing."[33] She added that "the flexibility of carbon is one of the great secrets of life on Earth."[34] Cosmic Education offers children the means to explore the wonder, the mystery, and the science of carbon, an element Montessori calls "one of the activators of the universe."[35]

The exploration of these elements and the way they combine and cycle through the spheres of the Earth lays the basis for what Thomas Berry has termed "ecological geography," the essential understanding of how planet Earth works.[36]

> The well-being of the Earth depends to an extensive degree on our understanding of the planet in its global extension, in its bioregional diversity, and in the intimacy of the component parts of the whole. We depend on this understanding of the Earth in all its diversity if we are to know how humans are to be present to the planet in some mutually enhancing manner. Such understanding is the proper role of ecological geography.[37]

The notion of a biosphere was first introduced by Eduard Suess and later developed by the Russian geologist Vladimir Vernadsky.[38]



> Vernadsky used for the first time the term biosphere in 1924, in his essay La Géochimie, which was based on a series of lectures he had given at La Sorbonne in 1922 and 1923. Philosopher and paleontologist Pierre Teilhard de Chardin (1881–1955), philosopher Henri Bergson (1859–1941), and mathematician and philosopher Le Roy (1870–1954) attended those lectures, and they and Vernadsky influenced each other's thoughts. It is the concept of biosphere related to biogeochemistry, expressed in La Géochimie, that is widely accepted today. Vernadsky understood biosphere as the external envelope of the Earth which is inhabited by living things and comprises both all the living organisms of the planet and the elements of inorganic nature providing the medium for their habitat. Thus, oxygen, carbon, hydrogen, nitrogen and other elements and chemical compounds involved in the vital process are constituent parts of the biosphere. As are the products of organisms' activities, such as animal burrows and lairs, birds' nests, deposits of lime and of fossil fuels. Even water is a component—a major component—of the biosphere [8]. Solar radiation, which is crucial for the maintenance of life on Earth, should be

33 Lynn Margulis and Dorion Sagan, *Microcosmos*, Berkeley: University of California Press, 1986, 48.
34 Ibid.
35 Montessori, *From Childhood to Adolescence*, op. cit., 73 (see chapter on carbon).
36 Thomas Berry, *The Great Work*, New York: Bell Tower, 1999. See chapter 8 on ecological geography.
37 Ibid., 96.
38 Vladimir Vernadsky, *The Biosphere.* (1929), trans. David B. Langmuir, edited by M. A. S. McMenamin, New York: Copernicus, 1998.

considered also a biosphere's component, and so should products of human activities. In fact, the human species is a major changing force in the current composition of the biosphere.[39]

Maria Montessori was also aware of the concept of the biosphere and of its central role in presenting the universe to the child's imagination.[40] The contemporary Gaia theory of James Lovelock comes close to the way Montessori describes the biosphere.[41] Montessori also spoke of the psychosphere in a manner similar to the way Vernadsky, de Chardin, and le Roy spoke of the noosphere, a term they invented in 1924 to describe the world of thought, human knowledge, and technological communication skills taking shape around the planet and in turn shaping its future.[42] This latter sphere has

expanded greatly over the last couple of decades and its integration presents new possibilities and new challenges. The new Systems View of Life seeks to unite the biological, the cognitive, and the social dimensions into one unified conception of life and consciousness.[43]

Montessori wrote:

> Life is considered by the geologist as an additional sphere surrounding the Earth. Besides the hydrosphere and the atmosphere there is also the immense multitude of vital energies that forms the biosphere. Were it not for these, were the Earth abandoned to the mercy of non-living energies, it would soon be plunged into the primitive chaos, in the confusion of elements. Humanity must have been allotted a major part towards the fulfillment of the common purpose. Its multitudes cover the Earth, contributing a new energy: the additional envelope of a psychosphere, which participates in the perfecting of nature.[44]

> Current thinking in the field of ecological literacy stresses the importance of not just comprehending the workings of ecosystems but of understanding that we are participants in a global system, a biosphere. Over the past 50 years or so the sciences of ecology and biogeochemistry have expanded their knowledge of how living systems great and small operate. Indeed, many scientists now see evidence that the Earth as a whole system is a self-generating, self-organizing, and self-maintaining system.[45]

The new Systems View of Life has, over the past 30 years, been stepping to the forefront of science. There have been major shifts in thinking. Some of these would include a change of perspective from parts to the whole, a multidisciplinary approach, an understanding that relationships are more important than objects, and that processes and networks must be understood in order to understand structures.[46] Maria Montessori's Cosmic Education perspective integrates fairly seamlessly with this new thinking.

Maria Montessori has given us beautiful, imaginative ways to open the child's mind and heart to seeing the Earth as what we might now call "a living system." It is clear that her vision in this regard was far ahead of her time. Recent discoveries and environmental crises point to the necessity of bringing this cosmic perspective to the next generation.

She writes in *To Educate the Human Potential*:

> …the 'Biosphere,' or sphere of life…is as intimately part of the Earth as the fur is of an animal, not something which suddenly rained on the Earth from outside. Part, then, of

39 Mercè Piqueras, "Meeting the Biospheres," *International Microbiology,* vol. 1, no. 2 (1998): 165–170.
40 Montessori*, To Educate the Human Potential*, op. cit., 28–29.
41 Capra and Luisi, op. cit., 67, 348.
42 Steffen, Crutzen, and McNeill, op. cit., 615.
43 Capra and Luisi, op. cit., 297.
44 Maria Montessori, "The Unconscious in History," *The NAMTA Journal,* no. 2 (1998).
45 Ibid., 349.
46 Ibid., 80–83.

> the Earth's body, like an animal's fur, is essentially one with it, its function is to grow with it, not only for itself, but for Earth's upkeep and transformation.[47]

She proceeds to describe how the truth that life is a cosmic agent can be presented to children's imaginations. Montessori describes using the power of large numbers to bring the child's mind to see the vastness of animal life on land, in the sea, and in the air, and the work of the "infinitely small beings…the microbes."[48]

Fritjof Capra and Pier Luigi Luisi writing in the 2014 text *The Systems View of Life* stress the necessity of what they call "an education for sustainable living."

> In the coming decades the survival of humanity will depend on our ecological literacy—our ability to understand the basic principles of ecology and to live accordingly. This means that ecoliteracy must become a critical skill…and should be the most important part of education at all levels—from primary and secondary schools to colleges, universities…and the training of professionals. We need to teach our children the fundamental facts of life—that one species' waste is another species' food; that matter cycles continually through the web of life; that the energy driving the ecological cycles flows from the sun; that diversity assures resilience; that life from its beginning more than 3 billion years ago, did not take over the planet by combating but by networking.[49]

To be ecoliterate is to understand the basic principles of ecology and to endeavor to live by them. Having a systems view of life, or what we would call in Montessori education "an understanding of the interdependencies in the natural and man-made worlds and between these worlds," provides the framework within which the human values of justice, compassion, love, beauty, and peacemaking can be examined.

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The principles to be understood and experienced as outlined by those currently defining ecoliteracy are:

- Interdependence
- The cyclical nature of ecological processes
- The importance of solar energy
- Partnership (cooperation and co-evolution)[50]
- Flexibility
- Diversity[51]

Montessori wrote that we have to develop an "eye that sees" patterns and harmonies in nature and in the built environment, in botany, zoology, geology, astronomy, and also in geometry, architecture, music, visual arts, dance, and poetry. An ecological mind and heart are multidisciplinary.

E. O. Wilson has recently written in his book *The Origins of Creativity* of the central importance at the present time of both scientists and scholars in the humanities working together, blending the best

47 Montessori, *To Educate the Human Potential,* op. cit., 28–29.
48 Montessori, *From Childhood to Adolescence,* op. cit., 29–33, 74, 91–92.
49 Capra and Luisi, op. cit., 356.
50 "Life did not take over the globe by combat, but by networking." (Capra, op. cit.)
51 Flexibility allows for adaptation to changing conditions and diversity relates to the importance of a multiplicity of feedback loops. (Capra op. cit.)

and most relevant insights from these great branches of learning to give us a better understanding of our human condition and our relationship with the natural world.

Here are Maria Montessori's own words as scientist and poet, as she describes the cosmic task of water:

Continents dissolve into the sea,

and seas yield to growing land.

Fantastic stalagmites and stalactites in caverns,

snow white towers and

pinnacles of glittering salt,

and turfaceous formations of marvelous colors

…the toiler for all this beauty

has been Water.

Water is the great builder, creating and transforming.

Drop by drop it leaves behind the load it was carrying.

It hurries in love to the ocean,

bearing gifts,

purifies itself,

floats to heaven in its lightest form, to return as rain,

and begin work again. [52]

There are several areas for further research which could add to our depth of understanding of Cosmic Education.

An expanded investigation of the biogeochemical cycles as understood by contemporary science, and the interrelatedness of the different cycles as could be discovered by elementary children.[53]

The children's work with the key elements in relation to the Montessori Needs of the Plant chart and related botany experiments leads naturally to a study of the periodic table of the elements. Montessori poetically alludes the periodic table as the alphabet of creation.[54] We now know so much more about this alphabet of the elements; their origins, their functions, and the stories of their discoveries. The exploration of the periodic table as it relates to both the physical and life sciences can be an important area of work for elementary children.

52 Adapted as a poem from Montessori's *From Childhood to Adolescence* op. cit., chapter on water.
53 Montessori charts for the carbon and nitrogen cycles developed at The International Centre for Montessori Studies in Bergamo deserve study in the light of our new understanding of the educational necessity of understanding these and other biogeochemical cycles.
54 Montessori, *From Childhood to Adolescence,* op. cit., 72, 84. 2019 is The International Year of the Periodic Table of the Elements.

Maria Montessori was well aware of the amazing work of the microbes (microorganisms) and writes about their essential work.[55]

Here is a short cosmic tale from a very special little microbe:

> I am a tiny microbe, a microscopic bacterium. Some call me the ferruginous microbe. My scientific name is *Gallionella ferruginea.* My species name comes from the Latin word *ferrum,* meaning iron, because we ferruginous microbes while living our lives and doing our work deposit iron. Scientists say, "we fix iron." You may have noticed the enormous deposits of iron in the Carboniferous Period on your Timeline of Life. That is because one of your great human scientists, Dr. Maria Montessori, knew about our important work. She dignified us by saying we were "a humble worker in Earth's laboratory." She said that my friends and I "performed an essential task in Earth's household economy." Please remember me when you see reddish-brown strata in rocks. And when you see the letters Fe on the Periodic Table of the Elements, think of me…the ferruginous microbe.[56]

> Many good and beautiful things owe their existence to the contact with microbes…[57]

> In order to fix the idea of these special tasks of life we call it the cosmic work of each being. A cosmic task is carried out by every being, even those that are microscopic. If we consider these different cosmic tasks we shall find that they are all interrelated.[58]

We now know so much about the microcosm, its evolutionary history during the Archaean and Proterozoic eons, and the essential role of microorganisms today in the maintenance of the planet. These amazing stories can be easily integrated into our biology, history, and geography presentations for older elementary children and into their own studies and research.[59]

The idea of the universal syllabus of studies, of a Cosmic Education, is clearly a great gift to future generations of children. Noel Laureate Paul Crutzen has written (2007) that the next few decades "will surely be a tipping point in the evolution of the Anthropocene" and that "humankind will remain a major geological force for many millennia."[60] Given this reality we must redouble our efforts to bring Cosmic Education to all of the world's children.

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55 Ibid., 74, 91–93 and Montessori *To Educate the Human Potential,* op. cit., 48–49.
56 Ibid., 48–49.
57 Montessori, *From Childhood to Adolescence,* op. cit., 92.
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59 See Big History: Threshold 5 Life, school.bighistoryproject.com
60 Steffen, Crutzen, McNeill, op. cit., 620.

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OF NATURAL SCIENCE, WOMEN'S HISTORY, AND MONTESSORI'S THEORY OF KNOWLEDGE

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OF NATURAL SCIENCE, WOMEN'S HISTORY, AND MONTESSORI'S THEORY OF KNOWLEDGE

by Kathleen Allen

Kathleen Allen's reverence for the stories of women naturalists spanning from the seventeenth through the twentieth centuries, and their parallel scientific interest in the documentation of life cycles through art and narratives, gives support to the child in history and nature that is so central to Montessori formal research and discipline. The parade of nearly a dozen short bios, from Beatrix Potter to Rachel Carson, frames not only a fresh outlook on science but also brings a soft feminist philosophical outlook while highlighting Montessori's connections to the natural world.

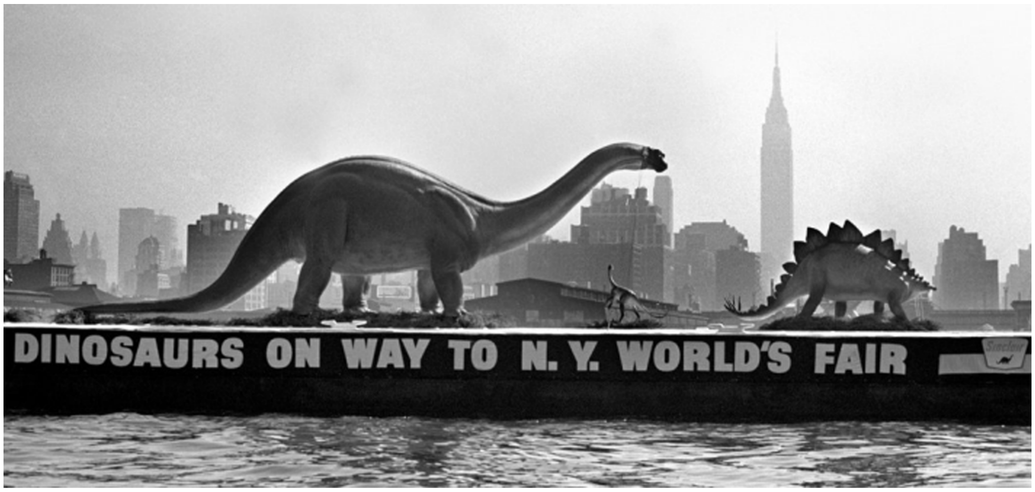
This chapter is based on a talk presented at the NAMTA conference titled Montessori History: Searching for Evolutionary Scientific Truth *in Cleveland, Ohio, April 20–22, 2018.*

Introduction

Every thing has a history. Every one has a history. And what is history but stories? I am fascinated by both the small stories and the grand stories. A couple of years ago, I retired from my Montessori classroom, and what did I do? I became a student again. I am currently pursuing a PhD in interdisciplinary studies with a concentration on history and writing at Union Institute and University in Cincinnati. This program is sort of Cosmic Education for grownups. The field I am most interested in currently is the history of women scientists. While this talk will definitely address its title "Of Natural Science, Women's History, and Montessori's Theory of Knowledge," I intend to keep it relaxed and low-key. Having entered the world of high academia, I prefer now to share little stories and a few images with you.

We are here in the Cleveland Museum of Natural History. This museum has many fascinating stories to tell, including that of Donald Johanson, who, in 1974, was named the curator of physical anthropology at the museum. And that was the year Johanson discovered "Lucy," the fossil of *Australopithecus afarensis* in Ethiopia, an extinct hominin dated to between 3.9 and 2.9 million years ago.

The most interesting connection I did not know that I have to this museum is the famous stegosaurus "Steggie" who sits out front. This life-size model is the second stegosaurus to reside on the grounds. The original stegosaurus, which lasted through thirty years of climbing children, has been replaced with Steggie 2, who has recently been repainted with more accurate coloring. My connection is to that original stegosaurus, which was created for the 1964 New York World's Fair, for the Sinclair Oil Company exhibit called Dinoland. These dinosaurs were made in the studio of Louis Paul Jonas, a prominent sculptor and creator of wildlife dioramas for museums. My brother, who was in high school at the time, worked at this studio in Hudson, New York, near our home. These life-size dinosaurs were carried by helicopter to a barge on the Hudson River and traveled south to New York City. The Cleveland Museum of Natural History then commissioned Jonas Studios to make an exact second stegosaurus from the World's Fair mold for display.



Museums are an incredible source of knowledge and wonder, and it is our responsibility to introduce children to museums early on. Modern museums combine the best in science and history and amazement. In my exploration of this museum, I noticed an exhibit on pterosaurs. Besides the marvels of these giant winged creatures, note this beautifully written text, enticing the potential visitor:

> They flew with their fingers. They walked on their wings. Some were gigantic, while others could fit in the palm of your hand. Millions of years ago, the skies were ruled by pterosaurs—the first vertebrates to achieve flight. Not dinosaurs, birds, or bats, pterosaurs were flying reptiles that lived in the world of dinosaurs 220 to 66 million years ago.

I also noted that like many museums of its kind, the museum's name includes the words "natural history." Just how is natural history defined by this museum? The founding goal was "to perform research, education, and development of collections in the fields of anthropology, archaeology, astronomy, botany, geology, paleontology, wildlife biology, and zoology." Other definitions of natural history or the natural sciences include the categories of: physics, chemistry, Earth science, ecology, oceanography, and meteorology. Natural history is generally the earlier term, centered on observation of plants and animals in their environments, whereas natural science grew out of that foundation with the addition of the scientific method and increasing empiricism. All of this grew from the "natural philosophy" of the ancients. When we talk about natural history, we really just mean natural phenomena, those things of nature. There are generally two key branches, life science and physical science, and all derives from the depths and heights of nature.

Dr. Montessori was a natural historian and she clearly directed us to support the child's innate interest in nature. In *The Advanced Montessori Method: Spontaneous Activity in Education,* she wrote:

> I would therefore initiate teachers into the observation of the most simple forms of living things, with all those aids which science gives; I would make them microscopists; I would give them a knowledge of the cultivation of plants and train them to observe their physiology.
>
> I would direct their observations to insects, and would make them study the general laws of biology. And I would not have them concerned with theory alone, but would encourage them to work independently in laboratories and in the bosom of free Nature.

Nature Study

I have been rather immersed in the late nineteenth and early twentieth centuries lately. There were powerful educational shifts during this time, including, of course, Montessori's theories. This period, also known as the Progressive Era, usually considered to be from 1890 to 1920, was, to put it simply, a response to the ills of society brought on in part by increasing industrialization, the growth of urban areas, and burgeoning population. With this came a reawakening to the importance of natural history, which itself arose out of a confluence of factors, including: the philosophy of the transcendentalists, the poetry of romanticism, the foundational nature studies by Louis Agassiz, whose quote "Study nature, not books" became a rallying cry, the Industrial Revolution, and the Depression of 1893, which led to the movement of people from farms to cities.

As a result, many children were growing up without the critical connection to the natural world; they were not staying on the farms and continuing the family traditions of cultivating the land. There was a growing consciousness concerning children and nature. The thought was that children must now be introduced to the natural world in their schools. Thus the Nature-Study Movement came into being. As an aside, this illustration of woodland bolete mushrooms was painted by Beatrix Potter.

Beatrix Potter

Anna Botsford Comstock (1854–1930) American

For my PhD I am studying a major figure in what became known as the Nature-Study Movement. Her name is Anna Botsford Comstock.

She was born in 1854 in western New York State, graduated from Cornell University in 1885 with a bachelor of science degree in natural history with a focus on entomology (the study of insects) and became the first female professor at Cornell. She wrote a 938-page book, *Handbook of Nature Study,* which was self-published in 1911, and is still in print. She married a fellow entomologist, her former professor, John Henry Comstock. Together they wrote many books on insects that Anna illustrated with her detailed wood engravings. They had no children, but frequently hosted their students for dinner parties and poetry readings at their home.

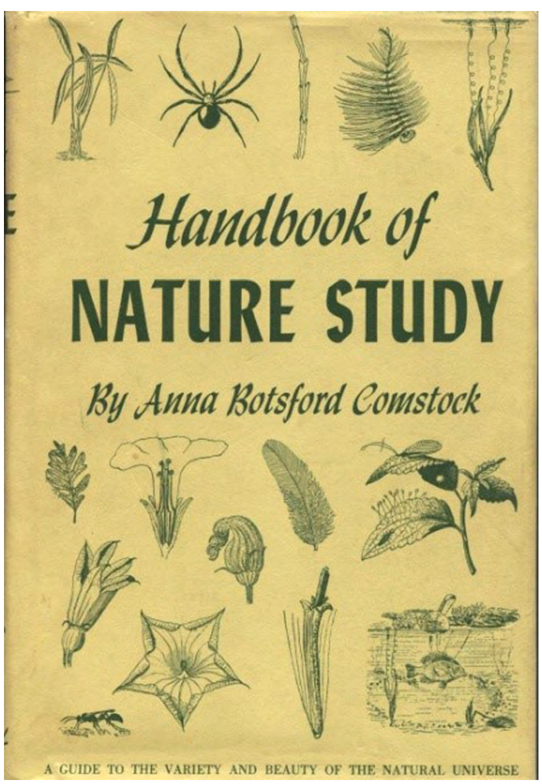
Anna lived what she taught. She was a gardener, a beekeeper, and a keen observer of the natural world around her. She was known for taking her college students out on field studies, to observe the insects in their habitat. One student remembered her catching butterflies:

Anna Botsford Comstock

[Mrs. Comstock] kirtled up her skirt almost to her knees. . . At the first sunlit clearing Mrs. Comstock gave a cry of joy and seizing her net from me, darted after a lovely, black-and-white striped swallowtail. "It's a zebra, a zebra," she cried, and presently managed to catch the butterfly, as it settled on a tall, waving flower.

At the beginning of her handbook, Anna defined nature study:

Nature Study is, despite all discussions and perversions, a study of nature; it consists of simple, truthful observations that may, like beads on a string, finally be threaded upon the understanding and thus held together as a logical and harmonious whole. Therefore, the object of the nature-study teacher should be to cultivate in the children powers of accurate observation and to build up within them, understanding. (1)



Anna developed the nature study program at Cornell and trained many teachers in her long career.

As an aside, I was also excited to discover that one of our preeminent woman scientists grew up reading Anna's *Handbook of Nature Study*—Rachel Carson. Here's a line from Rachel that echoes Montessori:

> Against this cosmic background the lifespan of a particular plant or animal appears, not as drama complete in itself, but only as a brief interlude in a panorama of endless change. (11)

Rachel Carson

Now compare these two quotes by Anna Botsford Comstock and Rachel Carson to Dr. Montessori's lines in *From Childhood to Adolescence:*

> There is no description, no image in any book that is capable of replacing the sight of real trees, and all the life to be found around them. Something emanates from those trees which speaks to the soul, something no book, no museum, is capable of giving. The wood reveals that it is not only the trees that exist, but a whole, interrelated collection of lives. (19)

While my studies have centered upon Anna Botsford Comstock, I have also begun to focus more generally on women scientists, especially those whose history has been lost or forgotten. The stories of women scientists are often underrepresented and it is important to bring them out of the shadows. Therefore, I am going to tell some little tales of a few women of science that are interesting to know. And, as we go along, we must keep in mind that Dr. Montessori was a scientist; therefore, all our Montessori work is based on science.

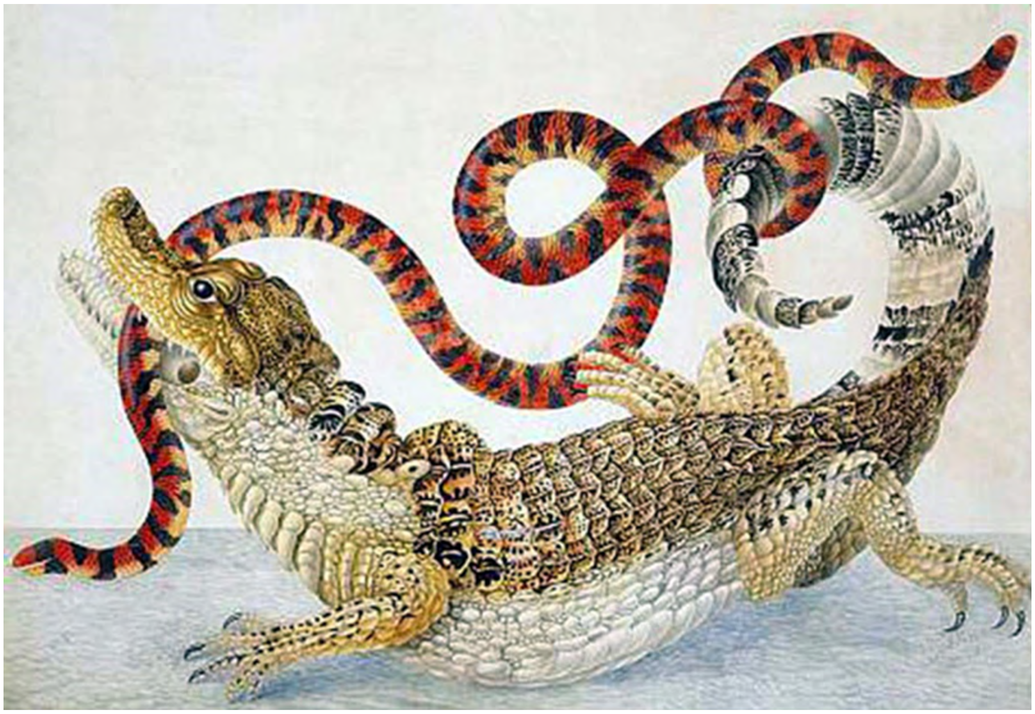
Maria Sibylla Merian (1647–1717) Swiss-German

Maria Sibylla Merian has a magnificent story to tell. Her superb scientific illustrations and her studies of insects have recently been rediscovered. Maria was Swiss in heritage, grew up in Germany, but spent much of her life in the Netherlands (when she wasn't adventuring.) Both her father and stepfather were artists, so she had an advantage: "Maria was able to learn drawing, watercolor, and still-life painting, and copperplate engraving from her stepfather along with his male pupils." Her uncle was in the silk trade, so Maria Sibylla had the privilege of many hours observing the caterpillars and moths in order to accurately illustrate them:

> Maria Sibylla was to say later [in her most famous book *Metamorphosis Insectorum Surinamensium*] that she had begun her observations when she was only thirteen: "From my youth onward I have been concerned with the study of insects. I began with silkworms in my native city [in Germany]; then I observed the far more beautiful butterflies and moths that developed from other kinds of caterpillars. This led me to collect all the caterpillars I could find in order to study their metamorphoses... and to work at my painter's art so that I could sketch them from life and represent them in lifelike colors." (Davis 143)

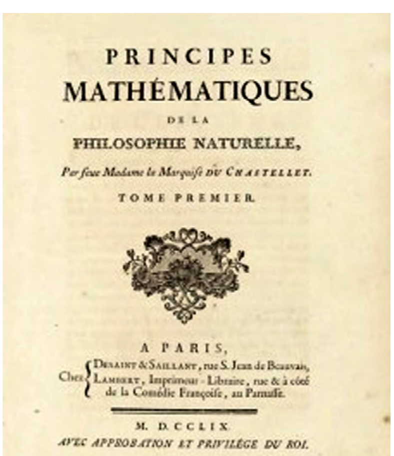
Maria's studies of butterfly metamorphosis were to be extremely significant, as the general seventeenth century superstition was that witchcraft or magic was somehow involved. In a children's biography, Maria Sibylla speculatively concludes: "When people understand the life cycles of creatures that change forms, they will stop calling small animals evil. They will learn, as I have, by seeing a wingless caterpillar turn into a flying summer bird."

In 1665 at the age of 18, Maria Sibylla married her step-father's apprentice. By 1692, she was divorced, and raising her daughters, Johanna and Dorothea, on her own, supporting her family with sales of her art. During all this she continued her work in entomology and botanical illustration. Her major adventure came in 1699 when she and her younger daughter Dorothea, also an illustrator, sailed off to the Dutch colony of Surinam in South America, partially funded by a grant from the city of Amsterdam, and the rest from a sale of her artwork. Maria Sibylla was 52 and Dorothea was 21. This was a scientific expedition to explore and record in art the insect, animal, and plant life of this exotic locale in South America. The plan was to spend five years traveling around, but serious bouts with malaria meant they had to return after two years. However, the artistic work and scientific observations that resulted from this expedition are exceptional and her art and writing have now been widely published.



Maria Sibylla Merian - Plate 69 from Dissertation in Insect Generations and Metamorphosis in Surinam, 1719, Sterling, Susan Fisher - 'Women Artists: The National Museum of Women in the Arts' - Abbeville Press Publishers, 1995.

For a seventeenth century woman and her daughter to undertake a challenging expedition across the seas shows Maria Sibylla's determination and independence. As a scientist and explorer, she was intruding into the male world. Because she directly observed insects, she was able to accurately paint them and to describe their life cycles. She kept copious notes of her observations. She was adaptable even in her art, as women were not allowed to paint in oils according to guild rules. So, she worked in watercolors and gouache. Even today her illustrations are admired for their beauty and detail.



PRINCIPES
MATHÉMATIQUES
DE LA
PHILOSOPHIE NATURELLE,
Par feue Madame la Marquise du Chastellet.
TOME PREMIER.

A PARIS,
Chez Desaint & Saillant, rue S. Jean de Beauvais,
Lambert, Imprimeur-Libraire, rue & à côté de la Comédie Françoise, au Parnasse.
M. DCCLIX.
AVEC APPROBATION ET PRIVILÉGE DU ROI.

Émilie du Châtelet (1706–1749) French

Émilie du Châtelet was a French mathematician, physicist, and natural philosopher. Her father was a noble and served as the principal secretary to Louis XIV. Emilie grew up in a privileged, highly educated household. In addition to her broad academic studies, especially in mathematics, science, and literature, she learned to ride and to fence. She also learned to play the harpsichord, to sing, to dance, and to gamble. She studied French, Latin, Italian, Greek, and German. When she was 18, her parents arranged her marriage to a marquis, who was 34. She had four children, but two died as infants. By the time Émilie was 26, she was studying algebra and calculus. She later became Voltaire's companion and they set up a scientific laboratory in his home. Their studies focused on physics and mathematics.

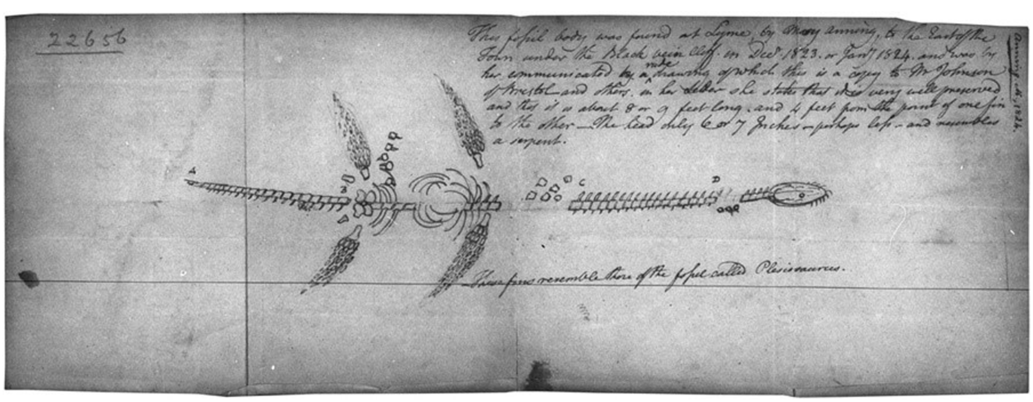
Emilie's best known contribution to knowledge is her translation of Isaac Newton's *Principia* from the original Latin complete with her own extensive commentary from her understanding of Newtonian physics. Emilie died in 1749 shortly after completing her book, which was published 10 years later.

Mary Anning (1799–1847) British

On the 19th of August 18oo, a powerful storm, raging with a fury of wind and rain, suddenly scattered the observers during a military display in a field near Lyme Regis, West Dorset, England, about 160 miles southwest of London on the English Channel coast. A woman and three small children found shelter under a towering elm tree. A slash of lightning struck the tree and only the youngest child survived. This fortunate toddler, Mary Anning, was to become one of the most famous fossil hunters of her time. Later some locals claimed the lightning strike was the reason she became such an undaunted collector.

With little formal education, Mary Anning had a scientist's curiosity and a researcher's doggedness. She faced hardships and sadness as her family was poor. Her father died when he fell off the cliffs while hunting fossils when she was only 10. Fossil collecting was her livelihood. Mary had apprenticed in fossil collecting with her father and surviving brother, and later under the tutelage of amateur paleontologist Elizabeth Philpot, one of the three maiden Philpot sisters who lived nearby. She loved what she did, even though as a young girl she began to collect the "curiosities" on the beach only in order to sell them to help support her family. She worked hard clambering along the dangerous cliffs of the Jurassic Coast, as it became known, seeking fossils of ammonites and belemnites. She also discovered an ichthyosaur, two plesiosaurs, and a pterosaur. Now, her fossil discoveries are displayed in many museums, but only recently have these been correctly attributed to her.

Today there is an increasing interest in and respect for Mary Anning's fossil collecting and her contribution to scientific knowledge. Some of her biographers have found it hard to imagine that a lower class, poorly educated girl could have had an impact on a male-dominated scientific community, but she did. What she began as an economic need soon became a passion. Being passionate about one's work is often listed as one of the traits of a creative personality. Mary was also persistent, energetic, and non-conforming, as scientists at the time were generally men.



A pen and ink sketch of a Plesiosaur by Mary Anning, 1824

Mary's story is a prime example of a tale that appeals to children. Here is a girl who had many disadvantages and little good fortune. Somewhere within her, there was a drive to know, to learn, to discover the next important fossil, to look upon what had been hidden in the rocks for millions of years. Hers is a story for children to hear, to begin to understand.

Dr. Montessori has something to say about fossils:

> Remains found in rocks allow the imagination to reconstruct past times, and realise an almost incredible age for our Earth. A million years becomes the unit, and twenty-five

> million years a mere episode of world-history. Such studies as geology and astronomy help us to conceive an eternity within infinity. They are the most fascinating subjects of our day, and children can and do feel their fascination. (*To Educate the Human Potential* 40)

Ada Lovelace (1815–1852) British

Another woman whose story is being revived is that of Ada Lovelace, who came from a noble heritage and followed a unique path. Ada was the only legitimate child of Lord Byron, the well-known British poet. She was raised by her mother Anne Isabella Milbanke, who split with Byron within months of Ada's birth. Ada was solely brought up by her mother, never knowing her father. Her education was focused on mathematics and science because her mother did not want her to become a dreamer like her father. Ada's mother wanted her to be calm and rational, not emotional and creative like her father. She hoped the study of math and science would suppress her daughter's imagination. So, Ada was given a world-class scientific education. Her imagination was not harmed in the least.

Ada was fascinated by the machines of the industrial revolution and visited factories. She was intrigued by the Jacquard loom, which could be set up to weave any pattern desired. Ada found out how the loom worked:

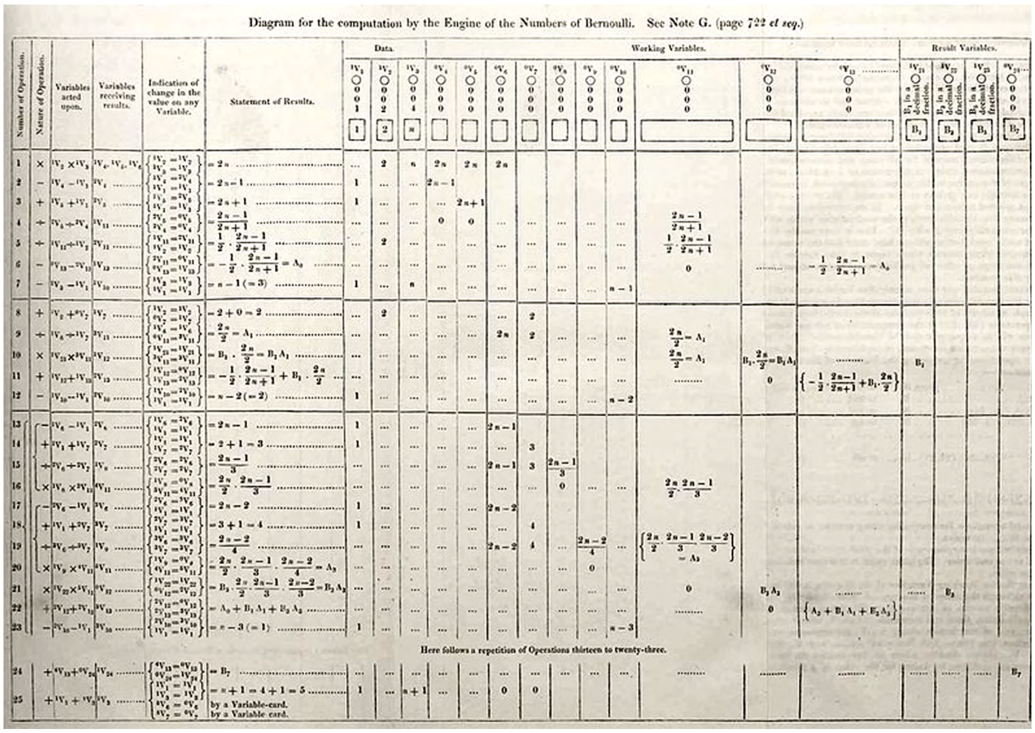
> The design was translated into a pattern of holes punched into heavy paper cards. Long chains of these cards were fed into the loom, giving it instructions. To change the design, you only had to change the cards. Ada was amazed. It was a brilliant idea—and not just for weaving cloth. Why not use punched cards to direct other machines for other purposes? (Stanley)

Later Ada met Charles Babbage, the mathematician and inventor, who had designed a calculating machine he called a Difference Engine. Ada and Babbage were to become friends and collaborators. Ada's life continued—she married and had three children, but never lost sight of her interests. At this time Charles Babbage had a new machine he was working on, a steam-powered mathematical Analytical Engine, using Jacquard's idea of punched cards. In effect, this invention was to be the "first fully programmable all-purpose digital computer." But Babbage needed to raise money. Ada stepped in to help Babbage by translating an article about the engine from French to English so it could be published. Her "Notes by the Translator" in this article "were almost three times as long as the original article—and far more important. Yet she wasn't credited by name, only the initials A. A. L."

> [Ada] was perfect for the job. She understood how the engine worked. She was a good writer. And she had the vision to see, better even than Babbage himself, how much more a computer could do besides just processing numbers. It could work with

any kind of symbol, from words to musical notes. Ada imagined the Analytical Engine writing text, composing music, reproducing images—even playing games like checkers or chess. (Stanley)

But the machine needed the proper mathematical input in order to do what Babbage wanted it to do. Ada took on this task by creating an algorithm "to program the machine to compute a complicated series of numbers called 'Bernoulli numbers'" (Robinson).



Ada combined her mathematical talents with her imagination and creativity and came up with a proposal to make the engine work. Unfortunately, Ada died at the age of thirty-six (she was buried next to her father). The engine was never built. The work of Babbage and Ada was forgotten for a long time but was rediscovered by such brilliant minds as computer pioneers Alan Turing and Howard Aiken. Ada represents the interdisciplinary dimensions of the creative mind: the distinct interplay of the reasoning mind and the imaginative mind.

Two other women I have recently stumbled upon are Florence Bascom and Alice Ball. Florence Bascom (1862–1945) was the first woman to receive a PhD from Johns Hopkins University and the second woman in America to receive a PhD in geology. Like many other early women scientists, Florence had to sit behind a screen during college lectures. Her research furthered our understanding of the origins and formation of the Appalachian Mountains, and she geologically mapped a good portion of the United States. In 1896 Florence was the first woman to be hired by the US Geological Survey. Note her working attire, complete with a compass in her hands. She is dressed in the standard female attire for the time: hat, shirtwaist, long skirt, necktie.

Alice Ball (1892–1916) was an American chemist who faced many obstacles to becoming a scientist. She was the first woman and the first woman of color to receive a master's degree (in pharmacological chemistry) from the University of Hawaii and later became a chemistry professor there. At the age of 23 Alice created the first effective injectable treatment for leprosy.

Now a little interlude: The photo below shows one of the main obstacles in the way of women scientists of this time. This is the first Solvay Conference in 1911 in Brussels. The institute was held as a gathering of the most illustrious figures in physics and chemistry. Marie Curie is the only woman there. In 1927 she was still the only woman there. Also present were Albert Einstein, Ernest Rutherford, and Max Planck.

Florence Bascom

Alice Ball

Hope Jahren (born 1969) American

Hope Jahren is an American geochemist and geobiologist who is currently a professor of geobiology at the University of Oslo, Norway. Her studies have focused on Eocene fossil forests. In 2016 her book *Lab Girl* was published and is a memoir of her experiences as a woman scientist interwoven with luscious passages about botany. An example:

> A seed knows how to wait. Most seeds wait for at least a year before starting to grow; a cherry seed can wait for a hundred years with no problem. What exactly each seed is waiting for is known only to that seed. Some unique trigger-combination of temperature-moisture-light and many other things is required to convince a seed to jump off the deep end and take its chance—to take its one and only chance to grow. A seed is alive while it waits. Every acorn on the ground is just as alive as the three-hundred-year-old oak tree that towers over it. Neither the seed nor the old oak is growing; they are both

just waiting. Their waiting differs, however, in that the seed is waiting to flourish while the tree is only waiting to die. (30)

How often is it that I find that the writings of these women scientists remind me of the writings of Dr. Montessori. In truth my Montessori years are deeply embedded now and I refer to her work often in my PhD studies. The following quote, found in *From Childhood to Adolescence,* is one of my favorites and reflects Montessori's lens on science, replete with factual knowledge framed in lovely prose:

In its entirety, the world always repeats more or less the same elements. If we study, for example, the life of plants or insects in nature, we more or less get the idea of the life of all plants or insects in the world. There is no one person who knows all the plants; it is enough to see one pine to be able to imagine how all the other pines live. When we have become familiarized with the characteristics of the life of the insects we see in the fields, we are able to form an idea of the life of all other insects. There has never been anyone who has had all the insects of the universe available to his view. (*From Childhood to Adolescence* 18)

Robin Wall Kimmerer (born 1953) American

My second contemporary woman scientist is Robin Wall Kimmerer, a plant ecologist and professor of environmental and forest biology at the State University of New York College of Environmental Science and Forestry in Syracuse, New York. She is deeply influenced by her Native American heritage and serves as the director of the Center for Native Peoples and the Environment. She describes herself as a "traveler between scientific and indigenous ways of knowing."

Her research centers on the habitats within the Adirondack Mountains in upstate New York. Her book. *Gathering Moss: A Natural and Cultural History of Mosses*, published in 2003 is another of my favorites:

Mosses are the amphibians of the plant world. They are the evolutionary first step toward a terrestrial existence, a halfway point between algae and higher land plants. They have evolved some rudimentary adaptations to help them survive on land, and can survive even in deserts. But, like the peepers, they must return to water to breed. Without legs to carry them, mosses have to recreate the primordial ponds of their ancestors within their branches. (21)

When I was looking for a parallel quote from Montessori's writings, this one stood out to me:

> The evolution of the plants of Earth is estimated to have taken about 300,000,000 years, from algae, mosses and lichens, through ferns to ever more complex forms of strength and beauty. Vegetation has accomplished its adventure with joy, conquering the Earth, aspiring to the heavens, gripping the soil with strong roots to support noble pillars, roofed with interlacing branches and leaves opening millions of hungry mouths in the sunshine for carbon dioxide. In living and growing to perfection they thus did their cosmic task, and accomplished a further one in death, for dead vegetation was transformed into Earth's inexhaustible supplies of coal. What could the men of our own day have accomplished without that coal, stored for him? (*To Educate the Human Potential* 47)

Just like the child in the elementary environment, I often find myself following a trail of intriguing crumbs of research, not exactly a wild goose chase, but adding interesting tidbits. Dr. Montessori noted in *From Childhood to Adolescence* in reference to preparing students for going out "We have him observe, for example, that moss is found mainly on the north side of trees in a forest." Now, I always heard that as a child, and just remembered it as an important fact. But I looked into where mosses grow and I found it has much more to do with the proper conditions of moisture and shade. Mosses are not sensitive to directionality. The north side of trees generally has better conditions. And in the Southern Hemisphere it is the south side of trees.

Lynn Margulis (1938–2011) American

Now I have saved one of my very favorites for last. Lynn Margulis died in 2011, and one of my greatest regrets is that I never got to meet her, even though her last professorship was at the University of Massachusetts in Amherst, Massachusetts, only a couple of hours from my home. I followed her scientific career and read and learned from her books. She was a radical thinker, persistent in her research, and faithful to her theories. I don't want to say too much more about Lynn because we will see the documentary about her tonight [the film *Symbiotic Earth* was screened at the April 2018 Cleveland conference].

Conclusion

Let me conclude with three reflections:

First, the words of Dr. Montessori in connection to the forgotten women of science:

> Let us in education ever call the attention of children to the hosts of men and women who are hidden from the light of fame, so kindling a love of humanity; not the vague and anaemic sentiment preached to-day as brotherhood, nor the political sentiment that the working classes should be redeemed and uplifted. What is first wanted is no patronising charity for humanity, but a reverent consciousness of its dignity and worth. (*To Educate the Human Potential* 27)

Second, these words from Teilhard de Chardin:

> The day will come, when after harnessing the ether, the winds, the tides, gravitation, we shall harness for God the energies of love. And, on that day, for the second time in the history of the world, man will have discovered fire. (86)

And lastly, I am reminded of my gratefulness for all those elder Montessorians who guided me, encouraged me, and gave me role models for my work. I am also thankful for the lessons I learned from all the children I was privileged to spend my days with in my long years of teaching.

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BIG HISTORY MEETS THE MONTESSORI METHOD

Lucy B. Laffitte *teaches science in context from the big bang to the future. She has written a newspaper column, founded an award-winning environmental radio program, created certificate programs, and developed digital learning objects for public television. She has a bachelor's degree in natural science from the University of Oregon, a master's in adult education/instructional design, and a doctorate in environmental resource management from North Carolina State University. She has been an educator at the Oregon Museum of Natural History, Tall Timbers Research Station, North Carolina Museum of Natural Science, Salt River Project, New England Wildflower Society, Rachel Carson Institute, the Nicholas School of the Environment, the Forest History Society, KQED, and UNC-TV. She currently teaches Big History at North Carolina State University and North Carolina School of Science and Math and serves on the board of directors for the International Big History Association.*

BIG HISTORY MEETS THE MONTESSORI METHOD

by Lucy B. Laffitte

Lucy Laffitte introduces the idea of Big History and illustrates its compatibility with Montessori's Cosmic Education vision. She writes, "Big History is transdisciplinary, an emerging discipline that fuses everything from the big bang to the future into a single academic field. Big History does not fit neatly into the siloed boundaries of academia because it transcends all the siloes. However, it allows us to glimpse a bird's-eye view of the way the disciplines are nested within each other." Laffitte presents the grandiose Montessori whole system of learning in a different idiom that suggests that the universe framework is not unique to Montessori.

This chapter is based on a talk presented at the NAMTA conference titled Montessori History: Searching for Evolutionary Scientific Truth *in Cleveland, Ohio, April 20–22, 2018.*

Big History is everything we see in the night sky. It is the greatest show on Earth. It is our past and our future. Every human that has ever lived has pondered it. It is in us and we are in it. Big History is science. It is based upon empirical evidence, wrested from the universe by huge telescopes, particle accelerators, satellites, and the Manhattan Project that cracked open the atom. The theory of radioactive decay gives us the ability to locate events on a real timeline—the age of the Earth, the age of the great oxygenation event, the age of rocks, the first animal, the meteor, primates, and fire-stick farming. It is also history based upon material culture artefacts and written records. Big History is world history, social history, African, Chinese, Indian, Persian, and Mesoamerican histories. It is women's history, queer history, and postmodern history. Big History is also a narrative with a beginning, middle, and end. As a grand story, rich with metaphors, it encodes the wisdom of our species. As an origin story, Big History generates meaning and purpose for humanity.

Big History is a narrative with a beginning, middle, and end. As a grand story, rich with metaphors, it encodes the wisdom of our species. As an origin story, Big History generates meaning and purpose for humanity.

Examples of lessons that can be given through Great History include that the universe is unfolding and that humanity is as much a part of the story as super novae and baby elephants. We learn stars have a life span, blinking on, aging, and dying, enriching the universe in death. Big History reveals an Earth so biophilic that it would have been shocking had life *not* developed, which underscores our yearning to search for other intelligent life. Big History replaces the selfish gene with a cooperative ontology among and between species. Big History allows us to see ourselves as a life form that has been able to erase the boundaries of our niche, allowing us to expand across the globe. And Big History tells us that the Anthropocene has arrived.

Big History is transdisciplinary, an emerging discipline that fuses everything from the big bang to the future into a single academic field. Big History does not fit neatly into the siloed boundaries of academia because it transcends all the siloes. However, it allows us to glimpse a bird's-eye view of the way the disciplines are nested within each other.

Creating Order with Big History

Imagine trying to order a set of twelve nested boxes containing the evidence for all the disciplines. How would you order them? Big Historians would arrange them in the direction of increasing complexity and by scale from largest to smallest. Let's conduct this thought experiment. In the biggest box, we would place the oldest, largest, and most widespread evidence that exists in the universe. As far as we know today, this box would hold the big bang. The first hundred thousand years of the universe is opaque to our senses, but we have hypothesized the existence of the Planck era, cosmic inflation, and a fluid exchange between energy and matter. Which of the disciplines can comprehend such abstract ephemera: The one that lives solely in our imagination and is communicated through the language of logic. We need mathematics to understand the earliest years of the universe.

We study the disciplines as if they are in separate boxes when in reality, they are nested within one another.

In the second largest box, we would place the evidence that flashed through the universe 380,000 years after the big bang: the ubiquitous hum of microwave background radiation, detectable from every direction of the universe. Which of the disciplines can penetrate the information in the electromagnetic spectrum? We use physics to measure temperatures, brightness, and motion encoded in the wavelengths of the spectra, and physicists tell us about star types, stellar evolution, galaxy structure, and super clusters of galaxies.

In the third box, we would place all the elements from simple hydrogen and stable helium to hungry oxygen to heavy lead. We would also collect the long chains of simple space molecules ranging in size from two to seventy atoms. Which of the disciplines can penetrate the structure of the elements and simple molecules and the rules that regulate them? We use chemistry to understand valence, reactivity, bonding, binding energies, and thermodynamics of matter.

The fourth box would be overflowing with planets and moons, asteroids, and comets—the complex molecular accretions found in solar systems. Planetary science is the discipline that unlocks the reasons for boiling hot planets, planetary rings, molten moons, as well as the nature of the atmospheres, hydrospheres, geospheres, and cryospheres on these other worlds.

The fifth box would be filled with rocks and minerals—chunks of native elements and the complex molecular cookie doughs of silicates, oxides, halides, carbonates, phosphates, and sulfides. Geology would be the discipline to unravel the life histories of these minerals and track them back to their origin in the plate tectonics of a molten planet.

The sixth box would contain the elegantly complex working molecules of life: the carbohydrates, proteins, fats, and nucleic acids, as well as the most multifaceted molecule in the universe, deoxyribose nucleic acid. Molecular biology is the discipline that works inside this box, bringing us insight about how the molecular machines accomplish the work of homeostasis, metabolism, development, and reproduction inside of a cell.

Continuing this thought experiment, we would see boxes filled with increasingly complex artifacts in a variety of laboratories. The seventh box would contain the fossilized tissues of past life that would be found in a paleontologist's lab, where the changing morphologies could be tracked to changes in their environment. The eighth box of biome data would fall to the ecologists to measure and model sustainable complex systems. The ninth box would contain primate bones and be found in anthropology labs where skeletons are analyzed for changes in brain, hand, and thumb size. The tenth box of arrowheads, stone tools, baskets, pottery, and artwork would fall to the archeologists to decode and to track humans' increasing mastery over the environment. The eleventh box would contain hieroglyphic-etched stones, goatskin parchments, and papyrus scrolls in addition to illuminated manuscripts, archives, and records that would sit upon the shelves beside miles of books in a historian's library.

With the specialization of humanity, the history box could be compartmentalized to include boxes for literature, art, music, theater, architecture, technology, languages, philosophies, religions, governance, cultures, and sociology, but a big historian would keep those in the history box to emphasize the newness and smallness of the human endeavor in light of its vast and ancient past.

So, what should be placed in the twelfth box in the very center of the nest? Big History would put the evidence of what has come to be called the *Anthropocene* in the box. The Anthropocene is the geologic epoch named "the age of man." Whether we like it or not, humanity is now in control of managing the biogeochemistry of the planet. It is not easy to sum up the potentialities of such a threshold.

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Who Is Involved in Big History?

The field of Big History was started by the publication of three seminal books. *The Structure of Big History* was published by professor of anthropology Fred Spier at University of Amsterdam in 2002. The next year, *Maps of Time* was published by professor of history David Christian at Macquarie University in Sydney, Australia. Four years later, *Big History: From the Big Bang to the Present* was published by professor of education Cynthia Stokes Brown at Dominican University in San Rafael, California, in 2007. In 2010, these three authors were joined by Grand Valley State University's world historian Craig Benjamin, UC Berkeley's planetary scientist Walter Alvarez, University of Southern Maine's anthropologist Barry Rodrigue, and Villanova University's political scientist Lowell Gustafson. And so it was that two historians, two anthropologists, a political scientist, a planetary scientist, and an educator coined the term Big History and launched an academic association to promote it. The International Big History Association (IBHA) publishes a monthly bulletin, an annual journal, and has convened four international conferences for members from sixteen countries across six continents.

As a professional organization, the IBHA edifies a group of people who are engaged in a wide variety of research. Some of us strive to discern themes that cross all of time: increasing complexity, increasing information, harnessing energy flows, emergence, and punctuated equilibrium. Others of us look for patterns among these themes to make predictions about the future, and we also write little

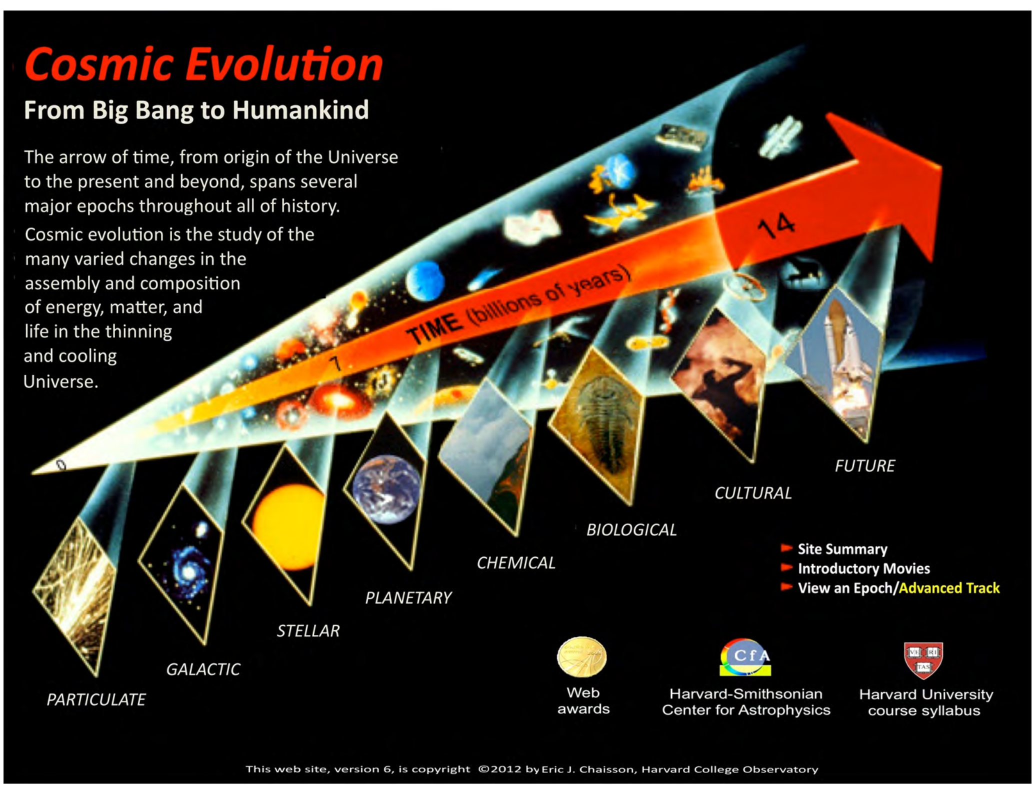

Image by Eric Chaisson

Stages of Cosmic Evolution

Big Histories. We look at the narrative through different lenses—by asking how Big History informs a variety of disciplines as diverse as economics, or English, or engineering. We recognize thinkers who think the same synthetic way, like Teilhard de Chardin, Thomas Berry, David Attenborough, Carl Sagan, Lynn Margulis, Rachel Carson, Eric Chaisson, Walter Alvarez, Fritjof Capra, and Peter Turchin. And we can ask questions about the Anthropocene—the geological period during which human activity is the dominant influence on climate and the environment. Is it rare for a dominant life form to change the biogeochemistry of the planet? Are all dominant life forms destined to change the climate of their planet? Is it possible for a dominant life form to change a fundamental nature of its behavior? Considering questions like these is uncommon outside of the field of future studies and science fiction, and yet they are vital if we are to adapt to a changing planet.

Resources for Teaching

There is a free, online curriculum for high school, middle school, and home school students. Software mogul Bill Gates is funding it. He was introduced to David Christian's Big History course in a televised great course while pedaling his exercise bike every morning. The course materials are continually updated with new scientific findings as well as ways to tweak and improve the pedagogy in the materials provided. The Big History Project course has been laid out for all teaching modalities: five days a week for a year, three days a week for a semester, a science course version, a social studies version, and a world history version. Gates has even paid for a free grading service for the substantial papers. The hidden agenda for the course is the improvement of reading, writing, and critical thinking. Clearly this is an echo of Montessori's Cosmic Education.

There are a handful of universities and colleges that teach courses in Big History. Macquarie University in Sydney, Australia, hosts the Big History Institute and has two faculty in the history department teaching and researching Big History. They are about to cut the ribbon on the Big History School, with free online materials for primary and secondary schools. Dominican University in

Photo courtesy of Lucy Laffitte

San Rafael, California, uses Big History as a first-year experience for *all* freshmen. Similar institutes exist in Japan, Korea, Russia, and India. The content of Big History is taught in a score of universities in the United States in a variety of disciplines: geography, anthropology, history, literature, design, and sustainability.

I have been teaching Big History to art college students, homeschool families, and middle school summer camps since 2012. One of the most powerful parts of my early years of teaching it was when, organically and without prodding, a hunger for discussing the future erupted in the class. Teaching Big History demands teaching about the future. It is quite telling that the only course at a research university with the word "future" in the title is about the commodity futures market. I now reserve time at the end of the course to teach the future, using the term *Anthropocene* to frame the discussion. At the end of the semester, I ask the students to reflect on the benefits and costs of the course. I would like to share some of the quotes:

- It makes it easier to incorporate discoveries in various fields into one's idea of the world because there is already background knowledge and is easier to make relevant connections.
- It streamlines the process of the exchange and mating of ideas across disciplinary fields, not possible from a singular disciplinary view.
- In order for an individual to recognize fully the importance of each and every component in our universe, you must acknowledge all of the energy and matter processed to create that component.
- It is wholesome for an intellectual society to construct a timeline that respectfully outlines the amount of construction put into the engenderment of literally everything.
- Learning about the innovation and discovery of our current knowledge is important for generating future knowledge.
- Considering a larger perspective demonstrates that the facts and effects about a specific subject are actually beautiful.
- Many fundamental discoveries have come from combining concepts.
- Every calculus integral, or computer circuit, or English paper that I write carries a different weight when you truly understand the greater context it fits into. At first, it may seem like studying the entire universe makes all these little assignments seem trivial, but I have noticed the exact opposite effect: I experience a powerful sense of purpose and gratefulness that makes the little things seem more meaningful.

Echoing among these statements is appreciation of both the grandeur of the world and firm understanding of the context for the human endeavor. We are not alien to the universe. We are a part of it and we have great work to accomplish. For more information on Big History, please visit www.school.bighistoryproject.com

Artist's logarithmic scale conception of the observable universe with the solar system at the center, inner, and outer planets, Kuiper belt, Oort cloud, Alpha Centauri, Perseus Arm, Milky Way galaxy, Andromeda galaxy, nearby galaxies, cosmic web, cosmic microwave radiation and big bang's invisible plasma on the edge.

THE ANTHROPOCENE: THRESHOLD 8

David Christian *is a distinguished professor of history at Macquarie University in Australia and the co-founder, with Bill Gates, of The Big History Project, which has built a free online syllabus on the history of the universe and is taught in schools all over the world. He is also co-creator of Macquarie University Big History School, which provides online courses in Big History for primary and high school students. He received his PhD from the University of Oxford. He has delivered keynotes at conferences around the world including at the Davos World Economic Forum, and his TED Talk on the history of the universe has been viewed over 7 million times.*

THE ANTHROPOCENE: THRESHOLD 8

by David Christian

"In the twentieth century, we humans began to transform our surroundings, our societies, and even ourselves. Without really intending to, we have introduced changes so rapid and so massive that our species has become the equivalent of a new geological force. That is why many scholars have begun to argue that planet Earth has entered a new geological age, the Anthropocene epoch, or the 'era of humans.'" David Christian presents a highly modern, scientific version of Cosmic Education using university interdisciplinary language. Like Montessori education, the Anthropocene chapter is an exercise in complexity theory.

Reprinted from Origin Story: A Big History of Everything. *London: Allen Lane/Penguin Random House (2018): 259–283. Reprinted with permission from the author.*

> *"We're no longer in the Holocene. We're in the Anthropocene."—Paul Crutzen, outburst at a conference in 2000*
>
> *"Man the food-gatherer reappears incongruously as information-gatherer. In this role, electronic man is no less a nomad than his paleolithic ancestors."—Marshall McLuhan,* Understanding Media

In the twentieth century, we humans began to transform our surroundings, our societies, and even ourselves. Without really intending to, we have introduced changes so rapid and so massive that our species has become the equivalent of a new geological force. That is why many scholars have begun to argue that planet Earth has entered a new geological age, the Anthropocene epoch, or the "era of humans." This is the first time in the four-billion-year history of the biosphere that a single biological species has become the dominant force for change. In just a century or two, building on the huge energy flows and the remarkable innovations of the fossil-fuel revolution, we humans have stumbled into the role of planetary pilots without really knowing what instruments we should be looking at, what buttons we should be pressing, or where we are trying to land. This is new territory for humans, and for the entire biosphere.

The Great Acceleration

If we stand back from the details, the Anthropocene epoch looks like a drama with three main acts so far and a lot more change still in the works.

Act 1 began in the mid-nineteenth century as fossil-fuel technologies began to transform the entire world. A few countries in the Atlantic region gained colossal wealth and power and terrifying new weapons of war. A huge gap opened between the first fossil-fuel powers and the rest of the world. That gap in power and wealth would last for more than a century and start closing only in the late twentieth century.

These differences created the lopsided imperial world of the late nineteenth and early twentieth centuries. Suddenly, countries of the Atlantic region, which had been marginal for much of the agrarian era, began to dominate, and sometimes rule, much of the world, including most of Africa and much of the territory once ruled by the great Asian empires of India and China. Outside the new Atlantic hub zone, the first impact of fossil-fuel technologies was mainly destructive because the new technologies arrived in the military baggage of foreign invaders. The *Nemesis,* the first iron-hulled steam-powered gunship, with its seventeen cannons and its ability to sail fast in shallow waters, helped England win control of China's ports during the First Opium War, from 1839 to 1842. The Chinese navy, once the greatest in the world, had no defense against such weapons.

Within decades, Europe's commercial and military power had undermined ancient states and lifeways. Textile production using spinning and weaving machines powered by steam engines ruined artisan textile producers in India, which had been the agrarian era's leading producer of cotton cloth. As Britain gained political and military control of the Indian subcontinent, it locked in these imbalances by keeping Indian textiles out of British markets. Even the building of India's major railroads benefited Britain more than India. Most of the track and rolling stock was manufactured in Britain, and the huge Indian rail network was designed primarily to move British troops quickly and cheaply, to export cheap Indian raw materials, and to import English manufactured goods. In the Americas, Africa, and Asia, growing demand for sugar, cotton, rubber, tea, and other raw materials encouraged environmentally destructive plantations, often worked by quasi-slave labor. In wars that pitted machine guns against spears and assegais, European powers carved up Africa and ruled it for the best part of a century.

Europe's economic, political, and military conquests encouraged a sense of European or Western superiority, and many Europeans began to see their conquests as part of a European or Western mission to civilize and modernize the rest of the world. To them, industrialization was a sign of progress. It was part of the transformative mission, first advocated in the Enlightenment, to "improve" the world, to make it a better, richer, and more civilized place for humans.

Act 2 of the Anthropocene was exceptionally violent. It began in the late nineteenth century and lasted until the middle of the twentieth century. During this act, the first fossil-fuel powers turned on one another. In the late nineteenth century, the Unites States, France, Germany, Russia, and Japan began to challenge Britain's industrial leadership. As rivalries intensified, the major powers tried to protect their markets and sources of supply and keep out competitors. International trade declined. In 1914, rivalry turned into outright war. For thirty years, destructive global wars mobilized the new technologies and the growing wealth and populations of the modern era.

Other parts of the world were sucked into these wars, and they were fought with as much brutality in China and Japan as they were in Russia and Germany. As the red mist of war descended over Europe, Africa, Asia, and the Pacific, warring governments competed to develop more destructive weapons. Science gave the combatants terrifying new weapons, some of which tapped the energies lurking within atomic nuclei. On August 6, 1945, a US B-29 Superfortress bomber flew from the Marian Islands in the Pacific and dropped an atomic bomb on the Japanese city of Hiroshima. It destroyed much of the city and killed eighty thousand people. (Within a year, another seventy thousand had died from injuries and radiation.) On August 9, 1945, a similar weapon was dropped on the city of Nagasaki.

Act 3 includes the second half of the twentieth century and the early twenty-first century. From the bloodbath of the world wars, the United States and the Soviet Union emerged as the first global superpowers. There were many local wars, most aimed at overthrowing European colonial rule. But there were no more major international wars during the era of the Cold War. By now, all powers understood there would be no victors in a nuclear war. But there were some close shaves. Soon after the Cuban missile crisis of 1962, President John Kennedy admitted that the odds of an all-out nuclear war had been "between one out of three and even."[1]

The four decades after World War II witnessed the most remarkable spurt of economic growth in human history. This was the period of the Great Acceleration.

Global exchanges were renewed and intensified. In the forty years before World War I, according to one influential estimate, international trade increased in value at an average rate of about 3.4 percent a year. For 1914 to 1950, that rate fell to just 0.9 percent; then, from 1950 to 1973, it rose at about 7.9 percent a year before falling slightly to about 5.1 percent between 1973 and 1998.[2] In 1948, twenty nations signed the General Agreement on Trade and Tariffs (GATT), which lowered barriers to international trade. Wartime technologies were now put to more peaceful uses. Oil and natural gas added to the energy bonanza of the nineteenth century, and so did nuclear power, the peaceful counterpart of nuclear weapons. Productivity soared, first in the leading fossil-fuel economies and then elsewhere. Consumption soared too as output rose and producers sought new markets at home as well as abroad. In wealthier countries, this was the age of the automobile, of TV, of suburban dream houses, and eventually, of computers, smartphones, and the Internet. A new middle class started to emerge. This was also when the industrial revolution began to spread beyond the old industrial heartlands. By the early twenty-first century, industrial technologies had transformed much of Asia, South America, and parts of Africa as completely and as fast as they had once transformed European societies. As other areas of the world industrialized, their wealth and power increased. There began to appear, once again, a world with multiple hubs of power and wealth. Within two hundred and fifty years of the first modern steam engine, fossil-fuel technologies had transformed the entire planet.

During the Great Acceleration, humans mobilized energy and resources on such an unprecedented scale that they began to transform the biosphere. That is why many scholars date the dawn of the Anthropocene epoch to the middle of the twentieth century.

Transforming the World: Technologies and Science

Innovation, propelled by cheap energy, was the main driver of change. Innovations created steeper gradients of wealth and power that encouraged competition, which drove innovation, in a powerful feedback cycle. Entrepreneurs and governments hunted down the innovations that might give them an industrial or military edge and invested in the businesses and scientists, the schools, universities, and research institutes that could generate and disseminate new technologies and skills.

The wars of the early twentieth century drove a forced march of innovation. During World War I, Germany ran short of natural fertilizers, and German scientists, led by Fritz Haber and Carl Bosch, figured out how to draw nitrogen from the air to make artificial fertilizers. Nitrogen doesn't like to react, so this was not easy. Prokaryotes had solved the problem billions of years ago, but Haber and Bosch were the first multicellular organisms to successfully fix atmospheric nitrogen. The Haber-Bosch process uses huge amounts of energy to overcome nitrogen's reluctance to combine chemically, so it was viable only in a world of fossil fuels. But artificial nitrogen-based fertilizers transformed agriculture, raised the productivity of arable land through the world, and made it possible to feed several billion more humans. It turned fossil-fuel energy into food.

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A liquid fossil fuel, oil, was first used in the late nineteenth century as a replacement for whale oil in lighting. The first internal combustion engines, developed in the 1860s and 1870s, showed how to generate mechanical force from oil. Unlike the steam engine, whose heat source was external to the engine's moving parts, in internal combustion engines, the heat from fossil fuels drove pistons or rotors or turbine blades directly. Internal combustion engines spread rapidly in the late twentieth century, largely because of their wartime use to transport soldiers and equipment and to power the first tanks. They were also installed in the first military aircraft, which pioneered the dark art of dropping explosives from the air. Once the wars ended, manufacturers of automobiles and planes turned to civilian markets to create a world in which more and more individuals owned and used cars or flew in planes. Global trade was transformed by oil tankers, container ships, and large planes.

Information lies at the heart of Anthropocene technologies. Information technologies were transformed when governments invested in a massive expansion of education and research, and businesses and corporations funded research to develop and disseminate new products and services. To break enemy codes, wartime governments funded research into the mathematics of information and computing.

This research, combined with the invention of the transistor in the late 1940s, laid the foundations for the computerization of science, business, government, finance, and everyday life in the second half of the century. Rocketry, also developed during the wars, would eventually send humans into space. Wartime governments had launched huge research programs to develop nuclear weapons. The American government's Manhattan Project developed the first atomic bombs, including the weapons dropped on Hiroshima and Nagasaki in 1945. These unleashed the energies of disintegrating uranium nuclei. The Soviet Union soon developed its own atomic weapons, helped by information leaked by spies from the Manhattan Project. Within a decade, the United States and the Soviet Union had also built hydrogen bombs, which released the much greater energies generated by proton fusion, the same mechanism that powers all stars. The first H-bomb was tested in 1952.

Much of this innovation was inspired by breakthroughs in the supercharged collective-learning environment of modern science. Albert Einstein developed his theory of relativity in the first two decades of the twentieth century. It improved on Newton's understanding of the universe by showing that matter and energy warped space and time, and this warping was the real source of gravity. Einstein also showed that matter could be converted into energy and that insight provided the scientific foundations for nuclear weapons and nuclear power. Quantum physics, developed in the same era, gave deeper insight into the strange, probabilistic world of atomic nuclei. Without that understanding, nuclear weapons, transistors, global positioning systems, and modern computers would not exist today. In the 1920s, astronomers such as Edwin Hubble found the first evidence that our universe began in a big bang. In biology, Darwin's idea of natural selection was combined with Mendel's understanding of heredity and the improved statistical methods of R. A. Fisher to lay the foundations for modern genetics.

These and many other new insights and technologies powered innovation and growth during the Great Acceleration. Increased productivity allowed human populations to grow faster than ever before. In 1800, there were nine hundred million humans on Earth. By 1900, there were one and a half billion. By 1950, when I was a child, there were two and a half billion humans, despite the huge causalities of the world wars. During my lifetime, human numbers have increased by another five billion. Such enormous numbers can numb the brain, so it's worth taking the time to grasp what they mean. In the two hundred years since 1800, the number of humans increased by more than six billion. Each additional human had to be fed, clothed, housed, and employed, and most had to be educated. The challenge of producing enough resources in just two hundred years to support an extra six billion humans was colossal.

Remarkably, the challenge was met with modern technologies, modern fossil fuels, and modern managerial skills. Productivity soared in agriculture, manufacturing, and transportation. Though food and other supplies did not always get to those who needed them, enough food was produced to feed more than seven billion people. The crucial changes were in the production of artificial fertilizers and pesticides, the use of fossil-fueled farm machinery, the building of thousands of irrigation dams, and the production of new, genetically modified crops. Modern farming technologies brought new land into cultivation, increasing the farmed area from half a billion hectares in 1860 to almost three times as much in 1960.[3] Fishing trawlers equipped with powerful diesel engines, sonar detection equipment, and massive nets sucked up most of the organisms in the area they fished. The fish catch rose from nineteen million tons to ninety-four million tons between 1950 and 2000, though overfishing means that many fisheries are now in danger of collapse.

Improved information technologies made it easier to accumulate, store, keep track of, and use the huge amounts of information that drove innovation and kept hugely complex modern societies running. Communications and transportation technologies transformed collective learning by creating, for the first time, a single, linked network of minds that that spanned the globe and could manage and track down new information in colossal electronic stores of information. The noösphere, the sphere of mind, became a dominant driver of change within the biosphere. Cheap but powerful networked computers gave billions of people access to more information than they could have found in all the libraries of the premodern world. When combined with the mathematically sophisticated techniques of modern statistical analysis, computers allowed governments, banks, corporations, and individuals to keep track of huge flows of resources. They also allowed instant communication between individuals anywhere in the world through telegrams, phones, and the Internet. If the sharing of information is what makes humans so powerful, computers multiplied that power many times over. As always, there were losses, too. Just as memory skills probably declined with the spread of writing, so calculating skills declined with the spread of computers and calculators.

By 2000, the fossil-fuel revolution embraced most of the world, including many older hub regions. The yawning gaps in national wealth and power of the late nineteenth century began to close. European powers, weakened by the world wars, grudgingly gave up their colonies, and older hub regions in Asia, the eastern Mediterranean, North Africa, and the Americas began to catch up in technology, wealth, and power.

Behind all these changes was the bonanza of cheap energy from fossil fuels. Coal production increased everywhere, but so did the production of oil and natural gas. New oil fields were developed in Arabia, Iran, the Soviet Union, and even along the continental shelves. In the Middle East alone, oil production increased from 28 billion barrels in 1948 to 367 billion barrels in 1972, just twenty-five years later. Natural gas came into its own during the Great Acceleration. Total energy consumption doubled in the nineteenth century and then rose by ten times in the twentieth century. Human consumption of energy rose much faster than human populations.

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Transforming the World: Governance and Society

The very nature of society and government was transformed by the new energy flows and technologies of the Anthropocene. Once, all humans had been foragers, and *government* really meant family relationships. After farming appeared, more and more people lived in peasant villages and supported themselves by farming. In farming societies, *government* meant, above all, mobilizing energy and resources from peasants. Today, most humans no longer gather or farm to produce their food and other necessities. They have become wage earners. Like the potters of ancient Sumer, they live on wages earned by doing specialized work. And that transformed the nature of government, because now governments had to become involved in the day-to-day lives of all their citizens. This is because wage earners, unlike peasants, cannot survive without governments. Farming villages could exist quite happily beyond the borders of the great agrarian civilizations, but wage earners depend on the existence of laws, markets, employers, shops, and currencies. A specialist wage earner, like a nerve cell, cannot survive alone. This is why a world of wage earners is much more tightly integrated than a world of peasant farmers. Modern governments regulate markets and currencies, protect the businesses that provide employment, create mass educational systems that can spread literacy to most of the population, and provide the infrastructure for the movement of goods and workers. To do all this, they must draw more and more of their subjects into the work of government and administration.

> [Humans] have become wage earners . . . And that transformed the nature of government, because now governments had to become involved in the day-to-day lives of all their citizens.

We can see the changeover to modern types of government in the nineteenth century, as industrialization took off, more and more peasants became wage workers, and governments began to mobilize more of their populations. Revolutionary France, transformed by revolution and under attack from most of Europe, was one of the first modern states to recruit soldiers systematically from the entire population. The government of the United States was also forged in a period of war during which it had to mobilize much of the population. To do that, governments needed detailed records on the number of citizens, on their health and fitness, on their education, skills, wealth, and loyalty. These were problems most traditional governments had been able to ignore. The governments of revolutionary France and the United States began to mobilize the loyalty of their subjects through democratization, which brought more of the population into the work of government, and through nationalism, which appealed to people's sense of a shared national community. They offered increasing numbers of their subjects (wealthy men, other men, and women, in that order) some role in government through elections. Through schools and the rapidly developing news media, governments tried to reach into the minds of their subjects and generate new forms of loyalty. Nationalism proved a powerful way of uniting people with different traditions, religions, and even languages. It mobilized traditional instincts of kinship by constructing in the minds of citizens a vast, imagined family of millions of people to whom they owed loyalty, service and, in the extreme crises of war, perhaps even their lives.

The total wars of the early twentieth century turned governments into economic managers, as they tried to mobilize all the people and resources of modern industrial economies. We can roughly track the increasing role of government in economic management. In the late nineteenth century, the French government accounted for about 15 percent of French GDP, a very rough measure of total national production. At the time, that seemed like a lot. Contemporary governments in Britain and the United States accounted for less than 10 percent of their GDP. The wars of the early twentieth century forced governments to intervene more actively in economic management, and by the middle of the twentieth century, their economic role had increased everywhere. In the early twenty-first century, the average share of national expenditure controlled or managed by governments in the countries of the OECD (Organization for Economic Co-Operation and Development, founded in 1960) was 45 percent of GDP, with most richer countries falling in the range from 30 to 55 percent.[4] Some governments, such as the communist regimes of the Soviet Union and China, attempted to micromanage the entire national economy. Modern governments also wielded coercive power on a much larger scale than traditional governments had, through armies and police equipped with modern weaponry. Such power would have been unimaginable to the author of the *Arthashastra*, the ancient Indian treatise on statecraft. Modern governments have a scale, reach, power, and heft that make even the most powerful governments of the agrarian era look like featherweights.

In an increasingly interconnected world, governance also assumed more global forms. By the late twentieth century, there were many political structures—not yet governments—that managed, advised and administered on a global scale. They included the United Nations, the International Monetary Fund, and large numbers of corporations and nongovernmental organizations (NGOs) such as the Red Cross, whose activities range across many different countries. These institutions represent, in embryonic form, a new, global level of governance that would have been unimaginable just a few centuries ago.

New Ways of Living and Being

Technological and political transformations have been accompanied by equally radical changes in human lifestyles—in the *experience* of life.

Modern humans live in ways that would have baffled, confused, and possibly terrified our ancestors. All the many different activities of a peasant household—plowing, sowing, harvesting, feeding livestock, milking cattle, cutting firewood, gathering mushrooms or herbs, bearing and rearing children, cooking the foods and weaving the fibers you have grown—dominated the lives of most people for thousands of years. Today, most farmers are entrepreneurs or wage earners. They work on huge industrial farms that specialize in just a few crops, some of them genetically engineered. They cultivate and transport their crops using lashings of fertilizers and pesticides and energy-hungry harvesters, tractors, and trucks. Modern farmers grow crops not to eat but to sell. They manage businesses. They borrow money from banks and buy their seeds, fertilizers, and tractors from large corporations.

Most people no longer live in villages but in towns and cities. Away from the fields, streams, and woods of the peasant village, they live in environments almost entirely shaped by human activity. As different jobs and skills and forms of expertise proliferate, people spend more and more time learning. Information—expert knowledge—is what counts, rather than the generalized skills of peasants. Increasing numbers of people enjoy levels of nutrition and health that were rare even a century ago, thanks to the productivity of modern agriculture and modern advances in medicine and health care. Modern anesthesia has ended the agony of most traditional medical interventions. (No longer is an amputation or tooth extraction made easier to bear by nothing but a shot of liquor.) Perhaps most remarkable of all, in just a century, these changes have more than doubled the average life expectancy of human beings.

Despite the wars of the twentieth century, interpersonal relations have also become, for the most part, less violent. There is a clear logic to this change, as coercion has become a less effective way of controlling behavior in the last century or two (when did you last see a public flogging?), and economic rewards and punishments have slowly taken their place (you probably *have* asked for a pay raise). Though today most people take for granted that slavery and domestic violence are wrong, it is important to remember that, as late as the eighteenth century, the slave trade remained quite respectable in most of the world; torture and execution were standard punishments even for petty crimes and widely regarded as a form of public entertainment; and beatings for corporal punishment were regarded as a normal and perfectly acceptable way of maintaining order within families and schools. Personal violence is still all too common, but, relative to the number of people in the world, it is much rarer than it used to be and no longer regarded in most of the world as an acceptable way of controlling behavior.

In a world of peasants, most lived close to subsistence, periods of shortage were familiar and common, and affluence meant, for most people, a solid home, freedom from debt, and enough money to pay taxes and feed and clothe a family. Today's consumerist world is utterly different. It is fueled by economic systems that, in the more affluent parts of the world, produce so much material wealth that their very survival depends on massive, sustained consumption by a rapidly growing global middle class. The idea of progress, which most of us take for granted, is also new. For the majority of human history, people assumed that, barring catastrophes, children would live much as their parents had.

Attitudes toward families and children have changed profoundly. In recent centuries, improved nutrition and health care began to lower child mortality, so more children survived into adulthood. Yet traditional peasant attitudes ensured that families kept trying to produce as many children as possible. Such attitudes, along with increasing food production, high fertility, and declining mortality helped drive the extraordinarily rapid population growth of recent centuries. Eventually, though, traditional attitudes began to change as families moved into towns, as educating and rearing children became more expensive, and as more children survived to adulthood. Urban families began to have fewer children, and fertility rates began to fall. The fall in fertility rates after the earlier fall in mortality rates is what demographers call the *demographic transition*: the emergence of a new demographic regime of low fertility and low mortality. And that explains why, in the twentieth century, rates of population growth began to slow, first in more affluent countries, and then throughout the world. It also helps explain fundamental changes in gender roles. Reduced pressure on women to spend their entire adult lives bearing or rearing children blurred traditional divisions between male and female roles and allowed women to take up roles from which they had been excluded during most of the agrarian era.

For anyone alive today, these aspects of modern lifeways are familiar, though the contrast with the now-vanished world of the peasantry may be harder to appreciate. Even harder to grasp is the staggering increase in the complexity of modern societies, the way every detail of your life is enmeshed in networks involving millions of other people who supply food and employment, health care, education, electricity, the fuel for your car, the clothes you wear. Each of these chains of interconnection may include thousands or millions of other humans linked together in networks of fabulous complexity. In idle moments at airports, I like to try to calculate how many people are involved in the project of building and maintaining an Airbus 380 and getting it from Sydney to London. Weaken any of these links, and our world can break down terrifyingly fast, as is apparent today in those parts of the world where state structures have collapsed. Kautilya, the author of the *Arthashastra*, would have said that humans in these places live under "the law of the fish."

Transforming the Biosphere

The fossil-fuel revolution and the Great Acceleration did not just transform human societies; they are also transforming the biosphere. The activities of humans are changing the distribution and number of living organisms, altering the chemistry of the oceans and the atmosphere, rearranging landscapes and rivers, and unbalancing the ancient chemical cycles that circulate nitrogen, carbon, oxygen, and phosphorous through the biosphere.

It has taken researchers a long time to realize that the impact of human activities is now as great as that of the major biogeochemical processes that maintain the stability of the biosphere. Without really understanding what we are doing, we are fiddling with the biosphere thermostats that have kept Earth's surface within habitable temperature for four billion years.

Carbon is central to the chemistry of life, and its distribution in the atmosphere, the sea, and the crust has helped determine temperatures at Earth's surface through the planet's history. Today, as we tap the energy in fossil fuels, we are pumping huge amounts of carbon dioxide back into the atmosphere. But not until the 1950s did scientists seriously consider the impact this might have on the carbon cycle. Charles Keeling began measuring levels of atmospheric carbon dioxide in Hawaii in 1958. Within a few years, he found that those levels were rising fast. Before the fossil-fuel revolution, human emissions of carbon dioxide were not large enough to affect the levels of atmospheric carbon dioxide. Today, though, human activities are releasing about ten thousand megatons of carbon dioxide into the atmosphere each year, and it is estimated that, since the industrial revolution, the total emissions amount to about four hundred thousand megatons of carbon dioxide.[5] How significant these changes are became apparent when researchers found ways of measuring carbon dioxide levels over hundreds of thousands of years. One method was to study ice cores, which contain tiny bubbles, trapped year by year, that can tell us the composition of the atmosphere on geological time scales. These showed that, in the two centuries since the industrial revolution, levels of atmospheric carbon dioxide had risen to levels higher than any seen for almost a million years.

The changes Keeling noted were real; they were striking; and they were transforming the carbon cycle. Rising carbon dioxide levels will mean warmer climates, and warmer climates will mean more energetic hurricanes, storms, and wind currents and rising ocean levels that will flood low-lying cities. The effect will persist for many generations because, once released into the atmosphere, carbon dioxide stays there for a long time. But carbon dioxide is not the only important greenhouse gas whose atmospheric levels have increased as a result of human activities. Levels of methane have risen even faster in the past two centuries, driven largely by the spread of rice-growing in flooded fields and the increasing number of domestic livestock. Methane is an even more powerful greenhouse gas, though it breaks down faster.

In the late twentieth century, computers allowed climate scientists to build increasingly sophisticated models of the likely impact of such changes on the atmosphere. Their models suggest that, with a few decades as greenhouse-gas emissions create a warmer world, melting glaciers and ice caps will raise sea levels, drowning many coastal cities, and increased heat energy and evaporation will ensure more erratic, unpredictable, and extreme weather patterns and make agriculture more difficult. With a few decades, global climates will look very different from the relatively stable patterns of the Holocene. As one US climate scientist puts it: "The climate is an angry beast, and we are poking it with a stick."[6]

Nitrogen is as vital for life as carbon. In 1890, human impacts on the nitrogen cycle were insignificant. Each year, humans extracted about fifteen megatons of nitrogen from the atmosphere, mainly through farming, while wild plants extracted about one hundred megatons, or almost seven times as much. One hundred years later, humans and plants had swapped roles. By 1990, the area of farmed land had increased to such a degree that wild plants were extracting only about 89 megatons, while human extraction of nitrogen through farming and fertilizer production had risen to 118 megatons.

Our impact on other large mammals has also been profound. In 1900, wild land mammals accounted for the equivalent of about 10 megatons of carbon biomass. Humans already accounted for about 13 megatons, while domesticated mammals—our cows, horses, sheep, and goats—accounted for an astonishing 35 megatons. In the next century, these ratios would get even more warped. By 2000, the total biomass of wild land mammals had fallen to about 5 megatons, while that of humans had increased fast (not surprising, given what we know of population growth) to about 55 megatons and that of domesticated mammals to an astonishing 129 megatons. This is a powerful indicator of the extent to which expanding human activities have squeezed out other species of large animals by taking more and more of the biosphere's resources.

The point is a general one. *Most* species of animals and plants that are not of immediate value to humans are declining in numbers. They are declining so fast that some speculate that we may be witnessing the early stages of another mass-extinction event. Rates of extinction are now hundreds of times faster than in the past few million years and approaching rates not seen since the last mass-extinction event, 65 million years ago. We humans have even managed to drive our closest relatives to extinction, including, probably, our hominin relatives such as the Neanderthals. Our closest living relatives, the chimpanzees, gorillas, and orangutans, are close to extinction in the wild.

The fossil-fuel revolution has magnified the scale of human impacts in many other areas. Mining, road-building, and the spread of cities now move more earth than is moved by erosion and glaciation. Diesel pumps suck fresh water from aquifers ten times faster than natural flows can replenish them. We are producing minerals, rocks, and forms of matter that never existed before. They include plastics (made from oil, and now accumulating in landfills in cities and within the oceans), pure aluminum, stainless steel, and vast amounts of concrete, a human-made rock whose manufacture is not a major contributor to carbon emissions. Such a proliferation of new substances has not been seen on Earth since the appearance of an oxygen-dominated atmosphere, around 2.4 billion years ago.[7]

One of the most terrifying of these changes is the increasing productivity of human weaponry. Just a few centuries ago, our most lethal weapons were spears or, perhaps, rock-throwing catapults. From the late medieval age, the gunpowder revolution, pioneered in China, gave us muskets, rifles, cannons, and grenades. World War II spawned weapons that degrade the entire biosphere in just a few hours; weapons with the destructive power of the asteroid that did in the dinosaurs.

Measuring Change in the Anthropocene

New flows of information and energy have woven humans, animals, and plants, as well as the chemicals of the earth, seas, and atmosphere, into a single system constructed primarily for the benefit of our own species. This system depends on huge flows of energy from fossil fuels. We can roughly measure the impact of these energy flows in the Anthropocene using figures in the statistical appendix [see chart at end of chapter].

The first thing that stands out is the sheer scale of change in recent centuries. In the past 200 years, human populations (Column B) rose from 900 million to more than six billion. That is the equivalent of adding 26 billion people in a thousand years, a rate of growth one thousand times faster than that of the agrarian era, in which, on average, about 25 million people were added each millennium. Such growth rates are unsustainable, and in recent decades, they have been slowing. Nevertheless, the figures illustrate the stunning impact on population growth of the fossil-fuel revolution.

Rapid population growth depended on huge increases in the energy available to our species (Column C). In the 8,000 years between the end of the last ice age and 2,000 years ago, human energy consumption increased by about 70 times. In just 200 years, between 1800 and 2000, total energy consumption rose by about 22 times, from 20 million gigajoules (20 exajoules) to 52 million gigajoules (520 exajoules). That rise is the equivalent of an increase of 2,500 exajoules every thousand years, a rate of increase 20,000 times as fast as in the agrarian era.

The energy bonanza from fossil fuels, like the energy bonanza from farming, paid for population growth, for the complexity taxes demanded by entropy, and, finally, for rising living standards but, on a much larger scale than in the agrarian era. And this time, the rise in living standards was not confined to a tenth of the human population but extended to a much larger emerging middle class.

Much of the energy bonanza for fossil fuels paid for increasing numbers of humans. It fed, clothed and housed the five to six billion people added to the world's population in the past two centuries. But the fossil-fuel bonanza was so much greater than that from farming that a lot more was left over for other uses. We know this because Column D shows that the energy available per person increased by almost eight times in the past one thousand years, while in the whole 8,000 years between the end of the ice age and 2,000 years ago, it had less than doubled. In the past 200 years, populations have grown at lightning speed, but energy flows have grown even faster.

A lot of the extra energy must have paid for the taxes demanded by entropy from increasingly complex societies. Much of that energy did no productive work or was dissipated as heat or in pollution or waste or the destruction of war. It was doing entropy's work of degrading complex structures. We have no good measures of the amounts involved, but they must be significant. Then there are the other complexity taxes, the energy and wealth that paid for the infrastructure of today's global societies. In the past 200 years, the size of the largest cities rose from about one million (a level that had barely changed in 2,000 years) to more than 20 million (Column F). Given the infrastructure of electricity, sewers, roads, and public transport needed for a modern city and the challenges of policing and regulating the activities of 20 million people crowded into a small area, it is apparent that this represents a quantum leap in social and technological complexity. Complexity taxes pay for the construction and upkeep of buildings, buses, trains and ferries, sewers and roads; they pay for garbage collection, the electricity grid, law codes, policing, prisons and courts, and the links by ship, plane, train, and the Internet that bind cities throughout the world into a single network. Without these different systems, all driven by huge flows of energy, the complex structures of a modern city would break down fast. And cities, in turn, are linked by a complex infrastructure of highways, laws, and electronic communications to hundreds of thousands of smaller towns, villages, and isolated settlements. Though we have no way of measuring it precisely, we can be sure that complexity taxes account for a large share of the energy from fossil fuels.

But the bonanza from fossil fuels was so massive that a lot of energy was left over for one more task: that of improving human welfare. As in the agrarian era, a disproportionate amount of wealth still supports a tiny elite, so, as in the past, we can allocate a significant share of the energy bonanza to elite consumption. But so huge was the increase in energy and wealth that, for the first time in human history, consumption levels began to rise for a growing global middle class of billions of people, far more people than the entire population of the world at the end of the agrarian era. Thomas Piketty estimates that in modern European countries, 40 percent of the population controls between 45 and 25 percent [*sic*] of national wealth. The appearance of this middle class was a new phenomenon in human history. And more and more people are joining the new middle class as the numbers of living in extreme poverty fall.

Paradoxically, increasing wealth also means increasing inequality, and even as the numbers living above subsistence are rising, the numbers living in extreme poverty remain higher than ever before in human history. Thomas Piketty estimates that in most modern countries, the wealthiest 10 percent of the population controls between 25 percent and 60 percent of national wealth, while the bottom 50 percent controls no more than 15 percent to 30 percent. This represents a decline in inequality in comparison with the era just before World War I. But in the early twenty-first century, inequality seems to be on the rise again, and the huge number of people alive now means that, in absolute terms, there are far more people living in extreme poverty today than there were in the past. In 2005, more than three billion people (more people than the total population of the world in 1900) lived on less than $2.50 a day. Most people in this group have seen few benefits from the fossil-fuel revolution and suffer from the unhealthy, unsanitary, and precarious living conditions of the early industrial revolution that were described so vividly by Dickens and Engels.

Nevertheless, a growing proportion of the human population is living well above subsistence. These flows have raised consumption levels and also levels of nutrition and health for billions of people. The measure that best captures this change is probably life expectancy (Column E). For most of human history, life expectancies at birth were less than 30 years. This was not because people didn't live into their sixties and seventies but because so many children died young and so many adults died of traumas and infections that would not have killed them today. Life expectancies barely changed for 100 thousand years. Then, in just the past 100 years, average life spans have almost doubled throughout the world because humans have acquired the information and resources needed to care for the young and old much better, to feed more people, and to improve the treatment and care of the sick and injured.

The contrast between the energy bonanzas from fossil fuels and from farming is striking. The energy bonanza from fossil fuels was so vast that, in addition to expenditure on reproduction, elite wealth, waste, and the infrastructure for complexity, there was enough left over to raise the consumption levels and living standards of an increasing proportion of humanity. This was a revolutionary transformation. It occurred mostly in just the past 100 years and primarily during the Great Acceleration of the second half of the twentieth century.

This is the face of the Good Anthropocene (*good* from a human perspective). The Good Anthropocene has generated better lives for billions of ordinary humans for the first time in human history. (If you doubt the improvement, think again about having surgery without modern anesthesia).

The Good Anthropocene has generated better lives for billions of ordinary humans for the first time in human history.

But there is also a Bad Anthropocene. The Bad Anthropocene consists of the many changes that threaten the achievements of the Good Anthropocene. First, the Bad Anthropocene has generated huge inequalities. Despite colossal increases in wealth, millions continue to live in dire poverty. And though it is tempting to think that the modern world has abolished slavery, the 2016 Global Slavery Index estimated that more than 45 million humans today are living as slaves. The Bad Anthropocene is not just morally unacceptable. It is also dangerous because it guarantees conflict, and in a world with nuclear weapons, any major conflict could prove catastrophic for most of humanity.

The Bad Anthropocene is not just morally unacceptable. It is also dangerous because it guarantees conflict, and in a world with nuclear weapons, any major conflict could prove catastrophic for most of humanity.

The Bad Anthropocene also threatens to reduce biodiversity and undermine the stable climate system of the past 10,000 years. The flows of energy and resources that support increasing human consumption are now so huge that they are impoverishing other species and jeopardizing the ecological foundations on which modern society is built. In the past, coal miners took canaries into mines to detect carbon monoxide. Today, rising carbon dioxide levels, declining biodiversity, and melting glaciers are telling us that something dangerous is happening, and we should take notice.

The challenge we face as a species is pretty clear. Can we preserve the best of the Good Anthropocene and avoid the dangers of the Bad Anthropocene? Can we distribute the Anthropocene bonanza of energy and resources more equitably to avoid catastrophic conflicts? And can we, like the first living organisms, learn how to use gentler and smaller flows of resources to do so? Can we find global equivalents of the delicate proton pumps used to power all living cells today? Or will we keep depending on flows of energy and resources so huge that they will eventually shake apart the fantastically complex societies we have built in the past 200 years?

Notes

1. Graham Allison and Philip Zelikow, *Essence of Decision: Explaining the Cuban Missile Crisis,* 2nd ed. (New York: Longman, 1999), 271.

2. Angus Madison, *The World Economy: A Millennial Perspective* (Paris: Organization for Economic Co-Operation and Development, 2001), 127.

3. Tim Lenton, *Earth System Science: A Very Short Introduction* (Oxford: Oxford University Press, 2016), 82.

4. Ha-Joon Chang, *Economics: The User's Guide* (New York: Pelican, 2014), 429, based on figures from the World Bank.

5. Lenton, *Earth Systems Science*, 82, 96–97.

6. The Scientist was Wally Broecker. Cited in David Christian, "Anthropocene Epoch," in *The Berkshire Encyclopedia of Sustainability, Vol. 10: The Future of Sustainability,* ed. Ray Anderson et al. (Barrington, MA: Berkshire Publishing, 2012), 22.

7. Jan Zalasiewicz and Colin Waters, "The Anthropocene," in *The Oxford Research Encyclopedia, Environmental Science* (Oxford: Oxford University Press, 2015), 4–5.

Statistics on Human History in the Holocene and Anthropocene Epochs*

ERA	A: YEAR 0 = 2000 BCE	B: POP. (Mill.)	C: TOTAL ENERGY USE Mill. GJ/Yr (= .001 Exajoules) (= B*D)	D: PER CAP ENERGY USE GJ/ Cap/Yr (1^{st} 3 = max. est.)	E: LIFE EXPECTANCY (Years) 1^{st} 3 = max. est.	F: LARGEST SETTLEMENT POP. (1,000s) 1^{st} = max. est.
HOLOCENE	– 10,000	5	15	3	20	1
	– 8,000					3
	– 6,000					5
	– 5,000	20	60	3	20	45
	– 2,000	200	1,000	5	25	1,000
	– 1,000	300	3,000	10	30	1,000
ANTHRO-POCENE	– 200	900	20,700	23	35	1,100
	– 100	1,600	43,200	27	40	1,750
	0	6,100	457,500	75	67	27,000
	10	6,900	515,500	75	69	

*Columns A through E based on Vaclav Smil, *Harvesting the Biosphere*, loc. 4528, Kindle; Column F based on Ian Morris, *Why the West Rules—for Now*, 148–49, plus 10,000 BP data interpolated.

LIVING BY GAIA

Lynn Margulis

LIVING BY GAIA

by Lynn Margulis

The 2018 Cleveland conference screened a documentary film titled Symbiotic Earth: How Lynn Margulis Rocked the Boat and Started a Scientific Revolution. *NAMTA conference participants enjoyed this memorable premier event in honor of Lynn Margulis, her symbiotic worldview, and her intimate community of scientific stars. This article is taken from a series of interviews in a book titled* Talking on the Water *and is substituted for the aforementioned video.*

Reprinted from Talking on the Water: Conversations about Nature and Creativity *by Jonathan White, Trinity University Press (2016): 57-77. Reprinted with permission from the Estate of Lynn Margulis.*

Lynn Margulis' [1938–2011] resume is a single-spaced, thirty-page small-print epic. She has written over 140 scientific articles (with titles such as *Ancient Locomotion: Prokaryotic Motility Systems and Homeostatic Tendencies of the Earth's Atmosphere),* fifty reviews, and eight books. Her first book, *Origin of Eukaryotic Cells,* was published in 1970, with its third version appearing in 1993 as *Symbiosis in Cell Evolution.* Several of her recent books, including *Microcosmos, Mystery Dance: On the Evolution of Human Sexuality,* and *The Garden of Microbial Delights* (a science book for middle school students and teachers), were coauthored with Dorion Sagan, Lynn's eldest son.

Lynn was born in Chicago in 1938, the eldest of four daughters. At age fourteen, she enrolled in an undergraduate program at the University of Chicago, where she was introduced to the natural sciences. After graduating, Lynn pursued an MS in zoology and genetics at the University of Wisconsin. In 1965, she received her PhD in genetics from the University of California at Berkeley. In 1970, Lynn moved to Massachusetts where, over the following twenty-two years, she raised four children and rose through the ranks to professor at Boston University. [She was a distinguished university professor for 13 years] at the University of Massachusetts at Amherst.

Lynn is the reigning queen of the microcosmos, and especially the biological kingdom Protoctista, which includes an estimated 250,000 algae, seaweeds, amoebas, and other little-known life forms. It's here that she learned her lessons in radical scientific thinking. In the sixties she started looking for DNA where no microbiologist thought it could be found: outside the nucleus of the algal cell. She found it, and her discovery supported a revolutionary theory of symbiosis in the origin of the cell. There are four parts to the theory, three of which are now accepted in mainstream science.

The historian William Irwin Thompson once said of Lynn, "If you wish to carry on as a 'child of Gaia' or a 'healer of the planet,' one interested in getting back to nature . . . then hold on to your environmentalist virginity, cross your mind, heart, and thighs, and don't read Margulis! . . . But, if you want to understand the intricate, fundamental systems by which life creates and maintains itself, then you just might find Margulis the right place to start all over again: from the ground up."

I flew into Amherst on the crest of a December storm. Lynn has had a party the night before with over a hundred guests, celebrating the release of *Concepts of Symbiogenesis,* by Liya Nikolaevna Khakhina, which Lynn had edited with a colleague. As usual, she had several conversations going at once. Before getting started on the interview, Lynn suggested we walk down to Nancy Jane's bakery to collect a batch of fresh muffins. Roosevelt, a midsized gray mutt Lynn had rescued from the animal shelter, was anxious to join us, so we followed him out the back door. Just through the hedge, we stumbled on the garden and red-brick home of Lynn's favorite poet, Emily Dickinson. "Do you know the poem about the hummingbird? she asked, never skipping a beat. Off we went, pulled by Roosevelt and the poems and stories of a woman who, like Lynn, was a phenomenon of brilliance, energy, and love for life.

Jonathan White: To get started, would you give a brief description of the Gaia hypothesis?

Lynn Margulis: The Gaia hypothesis states that certain conditions that sustain life are regulated by life itself. More specifically, the atmosphere and the sum of all life on the planet behave as a single integrated physiological system. The traditionally viewed "inert environment" is highly active, forming an integral part of the Gaian system.

The strongest evidence for Gaia comes from the study of atmospheric chemistry. The composition of the Earth's atmosphere differs radically from our nearest neighbors, Mars and Venus. Both of these planets have a carbon dioxide-rich steady-state atmosphere. The composition of their atmospheres makes perfect chemical sense. The Earth, however, is different. Loaded with reactive gases, its atmosphere makes no chemical sense whatsoever. For example, our air contains high levels of oxygen, nitrogen, and methane, among many other gases, which are violently reactive with each other. There is no way to explain this by chemistry alone. James Lovelock, the British atmospheric chemist who invented the Gaia hypothesis, puzzled over these atmospheric anomalies for a long time, concluding that the co-presence of such reactive gases are evidence that the atmospheric composition on Earth is actively regulated. The atmosphere is an extension of life. If the surface of the Earth were not covered with oxygen-emitting algae and plants, methane-producing bacteria, hydrogen-producing fermenters, and countless other life forms, its atmosphere would long ago have reached the same steady state of Mars and Venus.

Another argument for Gaia comes from astronomy. According to accepted models, our sun is 30 to 70 percent hotter today than it was in the early history of life on the planet. If the Earth's temperature were consistent with this increase in solar radiation, we would now be at a boiling point. But the temperature of the Earth has remained relatively stable and conducive to life for all this time! Some argue that this stability is just geochemical coincidence. We think that exponentially growing populations of gas-producing organisms have actively maintained surface temperatures within a range suitable for life.

JW: You're always insistent that the Gaia hypothesis is James Lovelock's, but you're often regarded as co-creator of the theory. Lovelock himself claims you were the only scientist who would talk to him about the hypothesis. When did you first meet, and how did your collaboration evolve?

LM: I met James Lovelock in 1969, but he had developed the Gaia hypothesis before then. In 1965, Jim was hired by NASA to evaluate the experiments for detecting life on Mars. In his evaluation, he and his colleague Dian Hitchcock found that the NASA experiments were inappropriate. They were designed to detect life in a place where life as we know it may not exist. "It seemed," Jim said, "that we were sent on an expedition to find camels on the Greenland ice cap, or fish among the sand dunes of the Sahara." In re-visioning the NASA experiments, Lovelock was convinced that he could use the principles of his hypothesis to detect life on Mars without ever going there. All he needed to know was the rate of gas production and removal in the atmosphere, and if these rates could be explained by physics and chemistry alone, there would be no life. If the Martian atmosphere could not be explained with physics and chemistry alone, then the chances of finding life would be much greater.

Lovelock considered calling his theory the "Biocybernetic Universal System Tendency/Homeostasis." He was talked out of this name by William Golding, author of *Lord of the Flies* and Lovelock's walking companion. What Lovelock needed, Golding said, was a good four-letter word to get the attention of his colleagues. He suggested that the theory be named after the Green goddess of the Earth, Gaia.

Meanwhile, my own work in reconstructing the history of early life on the planet was revealing that bacteria produce and remove all sorts of atmospheric gases. It was well known that plants produce oxygen, but what about the other gases? What about nitrogen oxides, hydrogen sulfide, carbon dioxide, methane, and ammonia? One or another of these gases is emitted by every lineage of bacteria I studied. I kept asking, "Why do scientists agree that oxygen is a product of life, but never discuss the thirty-five or forty other atmospheric gases? Are they a product of life too?" About six scientists with whom I talked said, "Go talk to James Lovelock. He agrees with you." And I'd say, "What do you mean he agrees with me?" I didn't pay any attention to this for a long time, but finally I wrote him. He wrote back saying he'd be coming to Massachusetts soon, so we could talk in detail then. He also wrote that, according to his calculations, the amount of methane in the Earth's atmosphere is off by an enormous factor. Given the temperatures, pressure, amount of oxygen and other gases in the atmosphere, and their known chemical reactions, there should be a virtually undetectable amount of methane. Yet methane is present in one or two parts per million everywhere. So, Lovelock asked in his letter, "Do you know of any biological process that could produce methane?" I was amused, because anybody who studies bacteria has heard of the methanogenic bacteria that live in anaerobic mud, cow rumen, and termites, among other places. They take in carbon dioxide and hydrogen and emit methane. I wrote Lovelock explaining this and he wrote again, confirming our meeting on his visit to New England. This was in 1972. And I remember the day he came to our family house in Newton, Massachusetts. When we answered the door, he said, "Hello, how are you? I answer to the name of Jim." He was very sweet and friendly. After a few minutes, he said, "You know, we've met before." And I said, "No, we haven't." "Yes," he said, "I'll tell you exactly when," and he pulled out a book called *The Origins of Life*, which I had edited in 1969. The book grew out of a very small meeting in Princeton that I had wheedled my way into because I was so fascinated by the topic. I think I was pregnant with my daughter, Jennifer, at the time. We looked at the list of attendees and, sure enough, Jim had been there. He had only spoken three sentences during the entire meeting. "Preston Cloud, the geologist, was so rude and aggressive to me," he said "that I couldn't get my ideas out. I never said a word after the introductory session."

We had a wonderful meeting, and from then on we kept up a regular correspondence. Jim sent chemical queries asking for biological processes that would account for them. He was less conversant in microbiology than I, so I helped him bring microbial awareness to his work.

It took at least two years before I understood what Jim's Gaia hypothesis really meant. In 1972 a fortuitous thing happened. Stewart Wilson of Polaroid invited Jim and me to his interactive lecture laboratory to tape a conversation on Gaia. For hours we talked back and forth. Jim asked about methane, and I'd answer by explaining how methane was produced by bacteria. He'd ask why the Earth is alkaline when our neighboring planets, Mars and Venus, are acidic. I'd suggest that ammonia, which is alkaline in water, is a common waste product of nitrogen metabolism. He asked if organisms could change the color of surface waters or sediments or if they could alter cloud coverage. He explained that the Gaia idea means that the Earth's surface is controlled and regulated by the organisms. "You mean organisms adapt to their environment?" I'd say. "No," he'd answer.

At the end of four hours of dialogue, Stewart rewound the tape so we could hear how it came out. He pushed the playback button and sat down. There was no sound, nothing. Stewart had forgotten to turn the recording switch on! "Oh my God," says Lovelock, "what are we going to do? I'm only going to be here another two days." And Stewart says, "I either have to abandon this whole project or we tape all over again." As it turns out, having to retape the session was probably the most important thing that ever happened to the early development of the Gaia hypothesis. It took two days of sessions and the time in between for me to understand something about what Lovelock was trying to say. The tape of the second dialogue served as the basis for three important papers: two technical and one popular summary that was published in the *CoEvolution Quarterly* in 1975.

JW: There are some points of the Gaia hypothesis on which you and Lovelock disagree. What are they?

LM: A recent article in *Science* magazine said, "Margulis is well known as the fervent supporter of the controversial hypothesis that the Earth is a single living organism." This kind of thing makes me angry because I never say the Earth is a single, live organism. Lovelock might, but not me. It's a bad metaphor. It leads to goddesses, mysticism, and other misconceptions about Earth. The Earth is an ecosystem, or the sum of many ecosystems. I see a big difference between a single organism and an ecosystem. For example, an organism produces gases, but it can't recycle its gaseous waste. It relies on the ecosystem for that.

JW: Lovelock likes to compare the Earth with a giant redwood tree. The interesting thing to remember, he says, is that the middle of the tree is dead wood with just a thick skin of living tissue around the circumference. Beyond that there's another dead layer, the bark, which protects the tree from the environment. Lovelock says the Earth is very much like that. You have the middle, which is molten and dead, a think skin of living tissue around the circumference, and beyond that, the atmosphere, which is just like the bark of a tree.

LM: That's an interesting comparison that helps make my point. A tree is an extraordinarily complex community. It not only includes the life you can see—the bugs and worms and birds—but also the myriad of microorganisms that live on the tree and in the soil below. What we see is a composite organism but not an ecosystem. The tree needs the rest of the ecosystem of which it is a part to deliver its carbon dioxide and water and recycle the oxygen it produces as waste. I agree that a tree is a better analogy for the Earth than a person, but there are still significant differences.

Lovelock would agree to all this, but he doesn't see a problem with using the metaphor of a living planet, particularly when speaking to the general public. He's a brilliant mischief maker, and realizes that people respond much more sympathetically to the image of a living planet than to a term like *ecosystem.* If the Earth is alive, it's harder to justify kicking it around the way we do.

Our differences are probably just a matter of how we approach the public. Lovelock is much more negative than I toward the academic establishment. He thinks academics tend to do anything to keep themselves in business. Consequently, he doesn't trust them and prefers to take his case directly to the public. I am more circumspect about this, perhaps because I work within academia. I think we're much better off if we express ourselves carefully and enlist scientists who can help develop the hypothesis. Lovelock is certainly right when he says the image of the Earth as an organism is far more moving than thinking of it as an ecosystem. But unscientific presentation alienates the very people we need most—the scientists, particularly geologists and biologists.

One of Lovelock's arguments for a life-centered metaphor is that we've lived too long with mechanistic metaphors. We think of life as a machine. We talk about the mechanisms of heredity, and we use defense analogies when we talk about fighting disease. I agree with Lovelock when he says, "What's wrong with having a living metaphor when the other metaphors are dead?" It's really just a matter of emphasis.

JW: Since the introduction of the Gaia hypothesis in 1972, both you and Lovelock have discovered that the idea is not necessarily new. Scientists such as Hutton, Lamarck, and Humbolt were emphasizing interdependence and relatedness in nature back in the eighteenth and early nineteenth centuries. Will you give a brief history of this kind of thinking?

LM: After the 1974 and 1975 publications, Jim and I started getting letters from all over the world with information about this way of thinking. We were both aware of the history of science, of course, but these letters brought to our attention a lot of unknown or previously obscure material.

James Hutton was one of the first persons to recognize that the proper study of the environment included the study of living organisms. He was a Scottish geologist, farmer, and natural philosopher who lived in the mid eighteenth century. Describing the Earth as a "superorganism," Hutton compared the churning of soil and the cycling of water between the oceans and land over time with the circulation of blood. Coming out of the age of the lifeless mechanical sciences, Hutton's view of a cyclical, organic Earth seems all the more revolutionary. He is the one who introduced the idea that life itself is a geological force, and that you can't study geology with only physics and chemistry.

The French naturalist Jean-Baptiste Lamarck, who lived about the same time as Hutton, also understood the planetary role of life, insisting on the link between geology, meteorology, chemistry, and evolutionary biology. "Living phenomena [do] not stand alone," he said, but ha[ve] to be seen as part of a larger whole, nature; indeed, they [are] only comprehensible when their constant interaction with the nonliving world [is] recognized." Lamarck is better known for his work in botany and zoology, and especially evolutionary theory, but his scientific philosophy is a precursor to our modern ecological worldview. His theories are largely rejected and trivialized to "inheritance of acquired characteristics."

Most of these early ideas are completely ignored or misconstrued. Hutton is celebrated as a geologist, but his views of "geophysiology" and the environment are all but unknown. Lamarck is passé. He gets one or two negative lines in a large college textbook of biology, and that's it. Unfortunately, much of the advancement of science has come through the last two centuries by compartmentalization. The specialized disciplines paid little or no attention to each other, much less to the unity of nature as a whole. This was particularly true of the Earth and life sciences, which ended up in separate buildings at the university, developing separate languages to address their separate fields. Lovelock calls this "academic apartheid," a phenomenon still prevalent today.

Among the few scientists opposing this fragmentation of knowledge was the German geologist Alexander von Humbolt, who lived and worked a little later than Hutton and Lamarck. He was a wonderfully dedicated scientist, working every day from the age of fourteen into old age. He was an accomplished cartographer too, and drew up plans for all kinds of weather instruments. The historian Jacques Grinvald says, "The evolution of living organisms, climate, ocean, and the Earth's crust is in fact a grand scientific idea deeply rooted in the nineteenth-century scientific world view associated in particular with Humbolt." The wide influence of Humbolt's work can be seen in early American studies of biogeography and ecology as well as in the thinking of other prominent scientists such as Charles Darwin.

The work of Vladimir Vernadsky, the most significant predecessor of these ideas, was not known to me at all until about 1978, when Stewart Brand sent me a piece of his work. I nearly flipped when I read it. With the exception of a few fragments like the piece Stewart had, none of Vernadsky's work was available in English until the very skewed publication of *The Biosphere* in 1986, an edition I cannot recommend. This was nearly fifty years later than the original French publication in 1929, *La Biosphere.* In that book, Vernadsky presents the notion of the whole Earth as an extraordinary single living phenomenon. He gives credit to the geologist Edouard Suess for having coined the term *biosphere* in 1875, but then takes the concept much further. To Vernadsky, the biosphere comprised the coevolution of "living matter" and the planetary environment of life. *Bio* means life and *sphere* means place, so *biosphere* is the sum of all life, including its environment. We owe our concept of the biosphere to Vernadsky.

In his wonderful book, *Traces of Bygone Biospheres,* A. V. Lapo says that Vernadsky's ideas were essentially unknown in the West except by G. Evelyn Hutchinson and Heinz Lowenstam. It was Vernadsky's son George, a Russian scholar at Yale, who introduced his father's ideas to the eminent ecologist Hutchinson in the last 1920s. Hutchinson was deeply impressed and helped to publish a summary of Vernadsky's work in the *American Scientist.* Ironically, the publication came out in January of 1945, just a few days after Vernadsky's death in Moscow.

The geologist Heinz Lowenstam dedicated his life's work to the study of minerals made by living processes. In the early 1940's, it was said that silica and calcium carbonate—the materials that make up animal shells and coral reefs—were the only minerals made by life. Using Vernadsky's notions of life as a geochemical force, Lowenstam showed that over fifty minerals are the result of living processes.

These are just a few of the scientists who has influence our present thinking about the Earth. As I said earlier, their contributions concerning the Earth as an integrated system that demands an interdisciplinary approach are not what you'd call mainstream ideas.

> The Gaia hypothesis, with its emphasis on mutualism and the reciprocity between life and the environment, appears to be a radically different view of evolution than Darwinism, which stresses natural selection through competition.

JW: The Gaia hypothesis, with its emphasis on mutualism and the reciprocity between life and the environment, appears to be a radically different view of evolution than Darwinism, which stresses natural selection through competition. Are these two theories really as incompatible as they seem?

LM: No, they're not. Lamarck, who was really the first evolutionist, said life is connected by common ancestry through time. *Evolution* means unfolding, literally, and refers to change through time. Astronomers talk about stellar evolution when describing the changes predicted for stars, and anthropologists speak of the evolution of cultural artifacts. When we talk about organic evolution, however, we're talking about the change in living organisms over the course of Earth's history. All modern biologists agree that evolution has occurred and that organisms are related. It's when we start talking about how evolution works that we get into big trouble.

It comes down to the question of how some beings survive and leave offspring and others don't. Who or what is doing the selecting? There are surely artificial selection pressures, such as the breeding of animals by human beings. In this case, humans choose traits they like, such as cuteness or meatiness or docility, and breed animals with those traits, over and over again. But what happens when there isn't an artificial selection process? Who or what does the selecting in the natural world? Is it God? Is it the environment? Is it the biota, the sum total of life on Earth?

Darwin, who was a Lamarckian, emphasized that evolution happens by "natural selection," which has come to be understood as the "survival of the fittest." These are the prevailing Western terminologies, but even the most devout followers of Darwin admit that evolution is not a single, simple process.

An example of one aspect of this process is the potential for run-away population growth that is present in every organism. Some fungi produce one hundred thousand spores per minute. Dogs can have six or seven puppies per litter three times a year. If elephants can have four elephants, and all of them live, it wouldn't take long before the world would be completely populated with elephants. These organisms don't often realize their reproduction rate, but the potential is absolutely intrinsic to living phenomena. So why is the potential never reached? Numerous environmental factors prevent this from happening. Usually, over 99 percent of offspring die because of restrictions such as lack of food, space, water, predation, disease and so on. Darwin called these checks, and these checks are the essence of natural selection. The fact that the potential for runaway population growth is present but never fully realized is natural selection. This selecting process works on all organisms at every stage of their lives.

Up to this point, there is no contradiction between Darwinism, or even neo-Darwinism, which is the combination of Darwin's views and modern population genetics, and the Gaia hypothesis. What people miss is that it's Gaia, the ecosystem of the Earth, that keeps any given population potential in check. Life regulates life. Gaia itself does the "natural selecting." Our critics don't understand this at all. Some insist that evolution is contradictory with Gaia. The truth is, the Gaian view simply includes the environment as an evolutionary factor.

JW: Are you saying that Darwin is misinterpreted?

LM: Yes, both Darwin and Lovelock are misinterpreted. Darwin was a wonderful biologist, but he was also full of contradictions. So full of contradictions, in fact, that you can find evidence in his work to support almost anything. Although he was anthropocentric at times, he also acknowledged the ancestral connection between human beings and other mammals. He discouraged the use of judgmental terms in evolution, such as describing one form as better or higher than another. Instead, he preferred to say that one form is more suitably adapted to a particular environment than another.

One criticism of Darwin is his lack of consideration for the environment. In his view, organisms adapt to the environment as if it were some independent entity with a capital E. There is no acknowledgement whatsoever of an active, mutually constructive exchange between any given life form and its living environment. The Gaian view, which accepts this mutual exchange, does not contradict Darwin's vision but takes it a step further.

It's no longer sufficient to study only biology in the pursuit of how evolution works. We need other sciences, especially geology and chemistry, if we're going to have any hope of understanding the whole system. The neo-Dawrinist view, which is our present paradigm for scientific thinking in the West, denies the need for chemistry, climatology, geology, comparative planetology, and the like. Instead, it promotes the capitalistic view that organisms succeed over time just because they leave the most progeny or are better at outwitting their neighbors.

One criticism of Darwin is his lack of consideration for the environment. In his view, organisms adapt to the environment as if it were some independent entity with a capital E. There is no acknowledgement whatsoever of an active, mutually constructive exchange between any given life form and its living environment. The Gaian view, which accepts this mutual exchange, does not contradict Darwin's vision but takes it a step further.

JW: Richard Dawkins, author of *The Selfish Gene,* is an outspoken critic of the Gaia hypothesis. He claims that life is made up of a network of small, self-interested components. A neo-Darwinist, Dawkins says, "Entities that pay the costs of furthering the well-being of the ecosystem as a whole will tend to reproduce themselves less successfully than rivals that exploit their public-spirited colleagues, and contribute nothing to the general welfare." Along with Dawkins, other scientists such as Ford Doolittle and Stephen Jay Gould insist that regulation of the planet by the biota would require foresight and planning—a kind of global-scale altruism that could not evolve through natural selection. Because the Earth itself does not reproduce, there would be no pressure for it to evolve as "the most fit planet." How do you respond to these criticisms?

LM: Neo-Darwinism's current funk over altruism reflects a failure to comprehend that every organism is part of a larger ecosystem, a system on which it depends for respiratory gas, water, food, and a sink for waste products. Are bacteria "public spirited" in ridding themselves of their waste, which happens to be the oxygen necessary for the other organisms in the system? Are those bacteria that don't produce oxygen "cheating" and thus at a reproductive advantage? I don't think so. Dawkins's claim that the Gaia hypothesis cannot be true because there is no evidence for competition between Earth and its neighboring planets reflects a preoccupation with the romantic, Victorian conception of evolution as a prolonged and bloody battle. Life, according to the neo-Darwinists, is a collective of individuals who reproduce, mutate, and reproduce their mutations. These mutations are assumed to arise by chance. The life-centered alternative to this view recognizes that, with the exception of bacteria, individuals with single genetic systems don't exist. All other living organisms, such as animals, plants, and fungi, are complex communities of multiple, tightly organized beings. What we generally accept as an individual animal, such as a cow, is really a collection of entities that together form an "emergent domain." The hind-gut of a termite, for example, is loaded with over twenty-five different kinds of bacteria and protists. Each of these organism types evolved over millions of years to perform a role in the "domain" that we recognize as a "termite." Without them, the termite would starve to death, because it alone is unable to digest wood. Yet termites acquire their vital supply of bacteria and protists not through their genes but in a peculiar ritual of feeding on the anal fluid of their fellow termites. There are dozens of examples of this mutual reliance, or what the philosopher Gail Fleischaker would call nestedness, in nature.

In this view, organisms do not compete in the neo-Darwinian sense—"nature, red in tooth and claw"—nor are they selected by God or some other "higher intelligence." It's not the individual but the community of life that evolves by cooperation, interaction, and mutual dependence. Life did not take over the globe by combat but by networking. As the philosopher David Abram says, "The interaction of life and the environment is more a dialogue where the environment puts questions to the organism and the organism, in answering those questions, puts new questions to the environment. The environment, in turn, answer with further questions."

JW: Some argue that while the Gaia hypothesis is a good idea, promoting a much-needed shift from a human-centered to a life-centered perspective, it is not—and never will be—provable. What is the current status on the search for mechanisms that demonstrate the existence of planetary regulation?

LM: Some work is being done, but it's a slow and complicated process. A current example is the study on cloud formation and temperature regulation over the ocean. Robert Charlson, an atmospheric scientist from the University of Washington in Seattle, has found that certain marine algae produce compounds that enter the atmosphere. Once there, they serve as particles around which clouds form. In warm temperatures, the algae bloom, causing more clouds. The increasing clouds reflect the sun's light and warmth back up into the atmosphere causing cooler temperatures and fewer algae. Few algae means fewer clouds, and fewer clouds mean a rise in temperature. With that, the cycle begins again. The net result is temperature regulation. Although this is an oversimplified presentation, it's a good example of how organisms affect the environment without sitting around in a committee and deciding what or how to regulate. I've seen satellite photographs of these tiny algae on the ocean's surface that extend fifty by two hundred kilometers.

Any mechanism that's regulating life has some sort of sensor that sends a signal to an amplifier. This is part of any feedback system, whether it be Gaian or manmade. The thermostat in your home is a sensor that sends a signal to the furnace, which amplifies the signal by turning on and generating heat. In the example I just gave of cloud-temperature regulation over the ocean, light or temperature is the signal these tiny algae receive. The amplifier is the potential for runaway population growth, which we talked about earlier. With lots of light and warm temperatures, these algae grow exponentially until, as a result of their growth, their conditions change again. The new signal, generated by more clouds, is less light or cooler temperatures. Thus the cycle reverses itself. This is the essence of a positive and negative feedback system. Now what's the difference between a manmade and a Gaian system? A manmade system is modeled by an engineer; in the Gaian system, feedback is an intrinsic property of the living system itself.

I see two basic approaches to the search for natural feedback systems. The first approach uses a model that results from the observation of global phenomena, like the temperature regulation by algae that I just described. The second approach attempts to remove the living elements of a miniaturized system in order to measure the effect their absence has on the rest of the system. Schwartzman, a geologist from Howard University in Washington, used this method in his studies of weathering. Until he proved differently, the breakdown of rock was considered only a physical and chemical process, primarily involving erosion by water and wind. Nobody who studied weathering needed to know anything about biology. By removing the organisms in a miniaturized system, Schwartzman found that the rate of weathering was reduced by a factor of a thousand! This is a great example of how the Gaia hypothesis, whether it's true or not, is promoting new scientific inquiry. Because of the obvious problems of miniaturizing a system or isolating elements within it, these experiments are not done often. Biosphere projects, like Biosphere II in Arizona, are another good example of this kind of approach.

When it was first stated, the Gaia hypothesis had three parts to it: temperature regulation, chemical regulation (oxygen, nitrogen, methane, and so on), and acidity/alkalinity (pH) regulation. New research, generated by the hypothesis itself, has revealed that the regulation and distribution of heavy metals, such as gold, iron, manganese, and copper may be added to that list. Water salinity in the oceans may be regulated by Gaia, too. We know that tons of salts are deposited there each year by streams and rivers. With no mechanism for removal, the salinity of the oceans should steadily increase, yet it has remained relatively stable for over five hundred million years. Why? I'm convinced that we'll eventually discover a Gaian mechanism for salt regulation. And, in that process, my suspicion is that we'll find evidence to support the argument that life influences lateral plate movement also.

A most striking current possibility is that life may play a role in retaining water on this planet. Venus and Mars are both very dry. Why? Because the elements—principally hydrogen—that water comprises escape from the atmosphere into space. In fact, it looks like a whole ocean's worth of water has escaped from Mars and Venus! The ozone layer in our atmosphere, which is made by life, prevents the loss of water to the upper atmosphere. That's one way life might be regulating the retention of water, but there are other ways too. For example, the scum that grows over the surface of ponds and lakes helps to prevent evaporation.

Ultimately, it doesn't matter whether the hypothesis is proved or not. The fact that it has generated new thoughts and new work is the best evidence of its value. It may be that all these experiments will show that life makes no difference at all, that the surface of the Earth is run completely by nonliving properties. That's one solution. Another solution is that life determines *all* regulation. The answer, of course, is probably somewhere in between. For example, no one claims that the amounts of neon, krypton, helium, and argon in the Earth's atmosphere are regulated by life. These gases, unlike carbon, nitrogen, and hydrogen, are not reactive.

JW: In *Microcosmos,* you say that the ancestor of all life first appeared in the form of bacterial cells 3.5 billion years ago. These earliest forms of life learned almost everything there is to know about living in a system, and what they learned is, principally, what we know today. These bacteria are still with us, you say, in our DNA and in our consciousness. We are surrounded by them and composed of them. This not only challenges the way we look at ourselves as individuals, but also the way we look at time and history.

LM: The past is all around us. Darwin's biggest contribution was to show us that all individual organisms are connected through time. It doesn't matter whether you compare kangaroos, bacteria, humans, or salamanders, we all have incredible chemical similarities. As far as I know, no one disagrees with this. Vernadsky showed us that organisms are not only connected through time but also through space. The carbon dioxide we exhale as a waste product becomes the life-giving force for a plant; in turn, the oxygen waste of a plant gives us life. This exchange of gas is what the word *spirit* means. Spirituality is essentially the act of breathing. But the connection doesn't stop at the exchange of gases in the atmosphere. We are also physically connected, and you can see evidence of this everywhere you look. Think of the protists that live in the hind-gut of the termite, or the fungi that live in the rootstock of trees and plants. The birds that flitter from tree to tree transport fungi spores throughout the environment. Their droppings host a community of insects and microorganisms. When rain falls on the droppings, spores are splashed back up on the tree, creating pockets for life to begin to grow again. This interdependence is an inexorable fact of life. As Vernadsky said, without this interdependence, no organism can hope to survive.

The fact that we are connected through space and time shows that life is a unitary phenomenon, no matter how we express that fact. We are not one living organism, but we constitute a single ecosystem with many differentiated parts. I don't see this as a contradiction, because parts and wholes are nested in each other.

JW: Biologically speaking, does all this mean we're not different than our hunter-gatherer ancestors of ten thousand years ago?

LM: We're somewhat different, of course. The corn seed you plant today is not exactly the same as the one you planted last year. There are differences and similarities, both.

We think of change in qualitative, hierarchical terms. We think of life as starting from a single cell and becoming more complex until we arrive at humankind, the pinnacle of evolutionary accomplishment. Most accounts of evolution don't even begin until a few hundred million years ago. But life began long before that. Of the 3.5 billion years that life has existed on Earth, the entire history of human beings from the cave to the condominium represents less than one-tenth of 1 percent. Feeding, moving, mutating, sexually recombining, photosynthesizing, reproducing, overgrowing, predacious, and energy-expanding symbiotic microorganisms preceded all animals and all plants by at least one billion years. Our powers of intelligence and technology, then, do not belong specifically to us but to all life. As Lewis Thomas says, "For all our elegance and eloquence as a species, for all our massive frontal lobes, for all our music, we have not progressed all that far from our microbial forebears. They are still with us, part of us. Or, to put it another way, we are part of them."

Life is a continuous phenomenon. You can't point to any of the great global catastrophes, like the one that wiped out the dinosaurs during the Cretaceous period sixty-five million years ago, and say that it extinguishes *all* life. It's true that thousands of species are now extinct, and that life itself has undergone huge changes in composition and detail. But in spite of all this, life's connection through space and time remains essentially unbroken.

JW: Apparently there have been over thirty of these catastrophic events in Earth's history, all of which were thousands of times more severe than anything humans can generate, including an all-out nuclear war. If the Gaian system is not threatened by these events, doesn't that shed a new light on the movement to "save the Earth?"

LM: Absolutely. It's not the Earth that's in jeopardy, it's the middle class Western life-style. Soil erosion, loss of nutrients, methane production, ozone depletion, deforestation, and the loss of species diversity may all be Gaian processes, but surely our behavior has accentuated them to the point of near catastrophe. It's quite possible that our ecocidal environmental policies and our insidious overpopulation will stress the system to such an extent that the Earth will roll over into another steady-state regime, which may or may not include human life.

The idea that we are "stewards of the Earth" is another symptom of human arrogance. Imagine yourself with the task of overseeing your body's physiological processes. Do you understand the way it works well enough to keep all its systems in operation? Can you make your kidneys function? Can you control the removal of waste? Are you conscious of the blood flow through your arteries, or the fact that you are losing a hundred thousand skin cells a minute? We are unconscious of most of our body's processes, thank goodness, because we'd screw it up if we weren't. The human body is so complex, with so many parts, yet it is only one infinitesimally small part of the Gaian system, a system which is far more complex than we can fully imagine. The idea that we are consciously caretaking such a large and mysterious system is ludicrous.

Many things we must do are more simple and straightforward than steering the planet into the future. We must stop using plastics for packaging or throw-away products such as fishing nets and champagne cups. We must stop using paper and plastic plates and tiny bottles of shampoo. We must use more silk, which is strong and durable as well as biodegradable. We could distribute grains grown in the Midwest to countries that need them. We must vastly improve the education of our children. So many things we can do are simple and tangible, yet living in an anti-intellectual country, we seem to lack the political will.

We need to recognize that humans have a large effect on the environment but relatively little effect on any idealized planetary system. Ultimately, it's the quality of life for humankind and other large animals that we affect most profoundly by our behavior. I don't think we should feel embarrassed or ashamed to show concern for our own survival. The Earth will live on until the sun dies—it's just a question of whether we'll be a part of its future.

HISTORY: HUMAN SOLIDARITY: MAN WHITHER BOUND

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by Baiba Krumins Grazzini

To Educate the Human Potential *by Maria Montessori, first released in 1948, conveyed the Montessori theme of human solidarity as a unifying force for human history and integrated the sciences of geography, chemistry, biology, and physics. The concluding chapter of this journal places the reader in touch with the great questions of life on Earth while linking each answer to the central theme of positive fundamental human needs and the role of humanity as a cosmic agent.*

Camillo Grazzini writes, "Indeed, Montessori goes so far as to say, 'I can never insist enough upon the importance of the study of history in all its details, for the education of the child to the idea of universal solidarity.' Thus, when it comes to the study of humanity, our aim must always be to make this profound realization of universal solidarity blossom in our children" (Grazzini 112).

The human solidarity concept is a second-plane orientation to the human story in the context of the environment from the beginning of all time. Montessori's "Human Solidarity" lecture is a positive projection of a unified world, past, present, and future; therefore, the final end of the elementary calls again to the adolescent to see all living things as one community bound with a sense of purpose to realize the highest potential of humans and nature as a great work within a peaceable kingdom.

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Today I shall talk about what's special about the Montessori approach to history, what makes it very different, in every way, from the usual or traditional or mainstream approach. Well, first of all, of course, our aim is different. Our aim is always different, and therefore it's also different for history, or indeed for any other subject area, as we saw when we talked about Cosmic Education yesterday. The aim is really always to help the children in their development. And when it comes to history, the aim is also that of building human solidarity.

In 1994, Camillo Grazzini gave a talk on Cosmic Education, which includes some very important sections on history: "Man—Whither Bound," which is actually the name of a chapter in Maria Montessori's *To Educate the Human Potential*; and "Human Solidarity in Time and Space," which is the title of a lecture Maria Montessori gave during the San Remo Congress in 1949. In both sections, he gives many quotes from these Montessori sources, and he concludes the latter section as follows:

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>
> Thus, when it comes to the study of humanity, our aim must always be "to make this profound realization of universal solidarity blossom in our children." (Grazzini 112)

If history is offered to the children with the Montessori approach, human solidarity becomes part of how the children develop. They come to feel this human solidarity and, if they feel this human solidarity, it means they have understood, they have seen realities that are normally hidden from our eyes. Then, Montessori says, it's almost as though humanity becomes sacred in their eyes, and therefore it would become absolutely impossible to kill or hurt other human beings.

In order to examine Montessori's idea of history, the first thing I want to do is to present what is, in all probability, a caricature of the usual approach to history. This, however, serves the purpose of providing a contrast. Therefore I am not saying that traditional history is inevitably always like this, or that the mainstream approach to history has not changed at all; I simply want to use this caricature so as to obtain the greatest possible contrast. Thus, in terms of a traditional approach, what is, or was, the span of time involved in the study of history? That involving civilization, which means little more than the last five thousand or so years. That was all for the traditional approach to history, and that was certainly the approach when I was young. Historians, at least once upon a time, only studied civilization. Although history was divided into ancient, medieval, and modern history, ancient history simply meant the ancient civilizations. Thus our "past," humanity's past, was limited to an extremely short span of time.

As for the content and the focus of traditional history, it does seem to be mostly about wars, treaties, cessation of wars, and generally speaking, horrors of all kinds. And who are the human beings who are actually presented in this particular story of mankind, in this mainstream story of mankind? They are always the important figures in the sense of the powerful and the famous; thus it is the powerful and the famous who are the heroes of this kind of history. National history is still usually taught in this manner.

As for the content and the focus of traditional history, it does seem to be mostly about wars, treaties, cessation of wars, and generally speaking, horrors of all kinds. And who are the human beings who are actually presented in this particular story of mankind, in this mainstream story of mankind? They are always the important figures in the sense of the powerful and the famous; thus it is the powerful and the famous who are the heroes of this kind of history.

All in all, traditional history was often a very pessimistic kind of story, a very pessimistic presentation of humanity. To illustrate this point of view, I want to give you a quote from Edward Gibbon, the English historian who wrote that famous work *The Decline and Fall of the Roman Empire:* "History...is indeed little more than the register of the crimes, follies, and misfortunes of mankind" (chapter III). There you have that authentically negative, pessimistic sort of vision, which is so characteristic of traditional history.

Now I want to give you various quotes from a rather special Montessori excerpt, where she's speaking about history. This excerpt is taken from *Pedagogical Anthropology,* which is not a book we would normally read. It is an early book, written a few years after she became involved with what was to become the Montessori approach. She writes this: "One branch of learning which might have utilized the important scientific discoveries regarding the antiquity of man, his nature considered as an animal, his first efforts as a laborer and a member of society, is pedagogy" (3). Montessori goes on to speak about the sorts of stories that we could tell the children and then she says:

> These marvelous accounts ought to be easily understood by children and to awaken in them an admiration for their own kinship with humanity, and a profound sense of indebtedness to the mighty power of labor, which today is rendered so productive and so easy by our advanced civilization, in which the environment, thanks to the works of man, has done so much to make our lives enjoyable.
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> But pedagogy, no less than the other branches of learning, has disdained to accept any contribution from anthropology; it has failed to see man as the mighty wrestler, at close grips with the environment, man the toiler and transmuter, man the hero of creation. Of the history of human evolution, not a single ray sheds light upon the child and adolescent, the coming generation. The schools teach the history of wars—the history of disasters and crimes—which were painful necessities in the successive passages through civilizations created by the labor and slow perfectioning of humanity; but civilization itself, which abides in the evolution of labor and of thought, remains hidden from our children in the darkness of silence. (4)

Montessori often uses metaphors to make a point, to help us to understand, and now she's going to use a metaphor of the railways, which in her day were the main means of transport and communication.

> Let us compare the appearance of man upon the Earth to the discovery of the motive power of steam and to the subsequent appearance of railways as a factor in our social life. The railway has no limits of space, it overruns the world, unresting and unconscious, and by doing so promotes the brotherhood of men, of nations, of business interests. Let us suppose that we should choose to remain silent about the work performed by our railways and their social significance in the world today, and should teach our children only about the accidents, after the fashion of the newspapers, and keep their sensitive minds lingering in the presence of shattered and motionless heaps of carriages, amid the cries of anguish and the bleeding limbs of victims.
>
> The children would certainly ask themselves what possible connection there could be between such a disaster and the progress of civilization. Well, this is precisely what we do when, from all the prehistoric and historic ages of humanity, we teach the children nothing but a series of wars, oppressions, tyrannies and betrayals; and equipped with such knowledge, we push them out, in all their ignorance, into the century of the redemption of labor and the triumph of universal peace, telling them that "history is the teacher of life." (4)

("History is the teacher of life" is really a quote from Cicero.)

With a Montessori approach to history, all of this changes: the span of time that we explore, the content, the focus. Something else also changes: Montessori's vision of history is optimistic, and this is crucially important for elementary children, particularly for young elementary children. An optimistic view is not one that is based on illusion or delusion; it simply means looking at the good side of human beings, at the positive achievements of human beings. The time will come when they will have to look at the other side of things; but they need to feel part of humanity, part of the *nazione unica*, before they come on to deal with what is bad, negative, cruel, etc.

I want to first consider the span of time. We could immediately say that Montessori deals with the whole of humanity: She doesn't start with civilization, as we know very well; she deals with all of humanity. But actually, it's even more than that. In *To Educate the Human Potential* (which is a hugely important reference source for us, for the Montessori approach to history for elementary children), it's clear that we don't start only with humanity because, from a certain point of view, history starts from the very very beginning.

In Italian, the word for history is *storia* and the word for story is also *storia*; where we use two different words, the Italians have one and the same word. (And the two English words have the same etymological root: the Latin word *historia.*) Thus story, understood as stories of truth, and history are one and the same, and where does the story begin? Right from the beginning. In this sense, although we say that the story of God Who Has No Hands, for example, is really for introducing geography; from another point of view it's also history, because God Who Has No Hands is the history or story of the universe. Thus history can start from the very very beginning, which is the story of the universe itself. Therefore history and geography go together; history and biology, or life, go together; history and the story of all humanity go together.

This very grand story is a story of evolution from the evolution of the universe and the Earth, to the evolution of life, to the evolution of human beings, to the evolution of culture and civilization. Moreover, since it's a story that has been, and is still being, unraveled for us by scientists, the wonderful thing about this story is that it's a universal story. Let's face it, each and every human group has always had its own story of creation: the creation of the world and mankind, the creation of its own people, etc. Consequently, each of these creation stories tends to focus on one particular human group, and they all vary from one human group to another. Our story, however, is a story for all time and for all people (and one which doesn't preclude other stories that one may wish to tell). Our story of truth, this huge story of truth, which unfolds in episodes (rather like the successive acts of a great drama), we can look on as a universal story for all of humanity; it's a story, if you like, for *la nazione unica.*

What is the importance of all this for the children? After all, we know we always have to think about the developmental aspects of what we are doing, of what we are offering. When the story, or history, is approached in this way, it means that, from the beginning, the children see themselves as part of the universe, part of life, part of all of humanity. There's a sense of belonging on a grand scale. We say we want to help the children understand that they're built out of the very materials of the Earth. Brian Swimme, in his book *The Universe Story,* says that we're all built out of the materials of the universe, out of stardust, because it was the stars that created all those materials of the Earth, the materials from which we're actually built. All of this means that there's a sense of solidarity that goes beyond a sense of solidarity with humanity: There's a sense of solidarity with the universe itself, with the Earth, with all of life. When we tell the story of life, it is easy to understand that all forms of life are our relatives. They can be more closely related or more distantly related, just as we can have very close members of a family or very distant members of a family; but nonetheless, we're related to all of life, we're part of life, and all forms of life are our relatives. And, if you like, so are the bacteria that we can look on as our planetary ancestors. To my way of thinking there is nothing irreligious or ignoble in all of this; on the contrary, I find it wonderful that such an incredible sense of relationship and solidarity can be evoked on such a very grand scale.

Now what about humanity itself? As we know, at a certain point in the story, we focus on that very special form of life to which the children belong; on that very special being, the human being. The human being comes with some outstanding gifts: a special mind, special love, hands. This specialness is constantly reinforced: We even have material, as we know, for reinforcing that. And again, the emphasis is on belonging to the whole of humanity. But it's not that we say to the children, "Oh, "*la nazione unica,"* and all that, because we don't. However, in effect, we are preparing for that kind of understanding; the whole way the history unfolds leads the children in that direction, and sooner or later they can reach that understanding. Let me reiterate yet again that the story of humanity begins from the beginning: It's not just about civilization, it's not just the story of the progress of civilization. Therefore it includes what we may think of as pre-history.

As you can see, the idea of what history is, determines the span of time involved and, inevitably, content and focus as well. To conclude this part, I want to quote Mario Montessori, who says (in an unpublished lecture given in 1950): "[our] history begins with the creation of the Earth, to then consider the coming of life, as well as the story of human beings."

We now have to examine further the other aspects of the Montessori approach to history. I've already said we put the emphasis on what's positive and good about humanity, before we come on to deal with the other side of the human story; and ultimately, our point of view is an optimistic one. What about the heroes of this history, of this Montessori approach to history: Well, if we're talking about the whole of humanity, the heroes are actually all human beings. That means not just the famous, not just the powerful; but also the ordinary human beings, human beings whom we could not possibly ever know. We know the famous by name; sometimes we know them by their faces, because we've seen their faces. But what about all of humanity, all the past generations as well as all the human beings that exist today? We'll never know them on a personal level; we'll never know their faces, we'll never know their names. The Italian expression Maria Montessori uses for all these countless human beings is *uomini senza volto,* which literally means "men without a face"; the faceless human beings, in other words, whose features we do not, and could not, know. But we do have to consider all of these ordinary human beings; all of them have that special mind, that special love, and those hands. And the story, then, is a story of how they lived their lives, of their struggles to survive, of how they tried to make life more comfortable for themselves. It's a story of work, really; it comes down to a story of human work. Human beings worked to satisfy their needs in order to survive not only physically but also psychically or spiritually. For the human being has a body, and therefore a drive to survive physically; but above all, the human being is spirit. Mario Montessori says that, when we think of the human being, we should think of a small body that serves a great spirit. That is why we always do have to emphasize the mind, the love, and the hands as the instrument of the mind.

We want to help the children to think about human life in the past, to imagine life as it was. Here's where the imagination is so important because, as Montessori says, how could we possibly explore the past, or history, without the power of the imagination? We have to imagine how human beings set about living their daily lives, satisfying their needs. And we do have certain key materials that help us. Those of us who are elementary trained know all of this perfectly well, but I want to suggest that we actually have three keys. One is the *fundamental human needs.* The fundamental human needs are both material: food, clothing, shelter, defense, transport; and spiritual: culture, art (and here you have the problem of how to interpret culture), religion, vanity. What is of vital importance about these needs is that they are universal. At all times, in all places, at all ages (child or adult), there are always these needs. What varies is how these needs are satisfied; that is what creates the differences and the diversity between the different human groups, in the past and also in the present. You know it's really important for the children to understand how we are all united. The fundamental human needs tell us that we all share the same needs, and this means that we're bonded in that way. And they also help to put diversity and difference into perspective. There is much talk of multi-ethnic classrooms these days; but even if we don't have multi-ethnic classrooms, it's important for the children to open up to all of humanity as it lives its life in the different human groups all over the world now, and also as it lived in times past. It's important to be able to both appreciate the diversity and also see what is common to all, what we all do share that makes us all belong to this same great nation of humanity.

It is really important for the children to understand how we are all united. The fundamental human needs tell us that we all share the same needs, and this means that we're bonded in that way. And they also help to put diversity and difference into perspective. . . . It's important to be able to both appreciate the diversity and also see what is common to all, what we all do share that makes us all belong to this same great nation of humanity.

The second great key is, of course, *migration*, and for this, too, we have a material, the migration charts. Living in their different human groups, human beings lived in different parts of the world, where nature provided different climates, different terrains, different plants, different animals, and so on. Each human group developed considerable knowledge of its own part of the world; of the biology, if you like, of the plants and the animals that were used in order to satisfy their needs so that they could eat, defend themselves from sickness, and so on. If that knowledge could become a heritage for all of humanity instead of for just one particular human group, then there could develop a huge group intelligence. Such an intelligence is not limited to only this human group, or this group intelligence, to this other human group; instead, it's as though every group commits to a great human intelligence. For that to happen it's important that knowledge, discoveries, inventions, ideas, be put into circulation. And the old way of putting these into circulation was through migration. People first carried the inventions, the discoveries, the ideas, on foot; then by other means of transport; and now these ideas can fly through the air, in a disembodied fashion. Once upon a time, in other words, knowledge and ideas had to be carried along physically, together with the people. Thus migration is another great key, because, as Montessori says, what good are discoveries and inventions that remain isolated, that don't serve humanity as a whole? It all has to go into circulation.

And the third key is that story, history, unfolds over *time.* To have a story, you need a certain kind of unfolding over time. Thus history in that sense, or indeed story in general, is embedded in a matrix of time. And then what's extraordinary (because human achievement is extraordinary), is that time itself, the keeping of time, measuring time, is a story in and of itself, yet another story of human achievement.

When we present the stories, history, to the children, we have to depend on their imaginations. (This is also important from a developmental point of view; because, if this is a time of sensitivity for the use of the imagination, the children have to use that imagination. History requires the children to use the imagination, and the children must use their imaginations for developmental reasons.) The children only live and know their own way of life; to explore the past, they have to imagine other ways of living, different ways of life, and we have to help them. Precisely because children tend to live in the present, they tend to think that things are unchanging; and that is so untrue. For little children it's fine. They have to live in an eternal present, and we shouldn't disturb or rush or hurry them. But the older children can understand that, in the end, everything changes.

Everything changes. I find that absolutely extraordinary; I, myself, feel wonder at that. Everything that we think is fixed and constant, if you look at it over a long enough span of time, actually changes. Just to give you some extraordinary examples, not too far off our main topic: The tilt of the Earth has changed; apparently, even the length of the day has not always been the same. Thus nothing ever remains the same; and that's very hard for children to imagine. Coming back to humanity, it is difficult for children to imagine (somehow we have to help them imagine) what it would mean to live life without the modern conveniences that we have now. There was life before the computer (and there still is); there was life before the cell phone (and there still is); there was life before etc., etc. We must help them imagine what that other way of life is or was.

Another thing in this story that is history and the human story, and that has to do with change, is that not only did human beings work with their hands; but also, because of those special minds, they learned to satisfy their needs in different ways over time. That's where you get the invention and the discovery. Therefore ways of life differ and change not only because of living in different parts of the world, but also because over time there were all sorts of inventions and discoveries, all of which we've inherited. And so many of those inventions and discoveries come without the names of the inventors and discoverers. For those of more recent times, we may know the names or, at any rate, we could find them out. But what about those of long ago? If we go far back enough, the greatest discovery is considered to be fire. How on Earth could we possibly know who first figured out how to control and use fire, or to make fire? And that's just one discovery that made such a huge difference. But there are an untold number of discoveries that have made an enormous difference to human lives, to our lives; and they were made by an untold number of people whose names we will never know. This, too, we want the children to understand; and it's part of this emphasis, this focus that we have, on all human beings and all human groups.

What's important about this approach is that it permits the children to see themselves as part of it all. You don't have to be famous, you don't have to have a lot of money, you don't have to go on television, in order to contribute and lead a worthwhile life. All children, all human beings, belong to this human drama. We are all the new protagonists of the Earth, the new actors in the drama of the Earth. Even though the child is not a prince or a princess and will never become a king or queen (if you go back in English history, for example, you find so much emphasis placed on kings and queens), even if the child were never to make the famous trip from the log cabin to the White House, does it really matter? The children can be themselves and play their important part in an ongoing drama that is the story of mankind: every single child. What more could we want from a developmental point of view?

As indicated already by the excerpt I gave you from Montessori's *Pedagogical Anthropology,* there really is so much to admire about human achievement; achievement which is always the consequence of human work, be it physical or intellectual. And if we really think about it, then surely we can feel nothing but wonder at how much humanity has achieved in such a short space of time. And when we recognize that, not only can we feel a sense of wonder but also a sense of gratitude and one of grateful belonging. The history that I was taught emphasized what was specific and not what was great and grand; it emphasized what was individual; it emphasized what were details; and, in terms of our lives, in terms of how I live my life or how you live your life, it often emphasized what was trivial. Furthermore, as we heard Montessori saying, it also emphasized the horrors of history.

What the children can come to appreciate (and this is also important from a developmental point of view) is that humanity constitutes a cosmic agent. Montessori talks about humanity or mankind as God's chief agent on Earth for creation. Any cosmic agent, any agent of creation, is an agent of change; but humanity is a cosmic agent that brings about change in an extremely rapid way, the rate of which is accelerating all the time. Humanity's achievements, for better or for worse, have involved the transformation of the Earth. Human beings have built a supernature for themselves, an environment that's literally above nature and one on which we all now depend.

To bring that home, I would like you to imagine this: Take away supernature, take away human work; imagine that everything in this room, in this building, that has to do with human work, is taken away. What is left? The whole building disappears with everything it contains; all our clothes fly off; and we end up sitting on the ground naked. That's what happens if you take away human work, if you take away supernature. And it makes us understand how much we depend on supernature, on civilization, on what is the creation of humanity; it helps us to understand why Maria Montessori calls humanity God's chief agent on Earth for the continuation of creation.

I want to reiterate and reinforce that what is also amazing, is the space of time that's involved, the time it's taken for humanity to create our supernature. Whatever you consider the duration of human existence to be, whether you consider it to be one million, two million, or two-and-a-half million years (which include the five or six thousand years of civilization), it's all just the blink of an eye in relation to the age of the Earth, in relation to the duration of the Earth's existence. And how did it happen? We come back once again to human beings with their special gifts, with what makes them different from all of the other life forms on the Earth. Yes, they were driven by their needs; yes, they had to satisfy those needs in order to survive; but they always learned how to survive and how to satisfy their needs in very different ways through their discoveries and inventions. Thus, starting in a very simple way, they learned to use the kingdoms of nature and to harness the powers of nature, to make themselves stronger and more powerful.

There is an image that I like to use for this. Let's suppose that we compare nature to an eagle, and human beings to a sparrow. If the sparrow flies with the eagle, actually rests on the eagle, and the eagle flies as high as it can, then the sparrow, who's just rested with the eagle, can actually fly that little bit higher than the eagle. The forces of nature are far more powerful than those of human beings. So what permitted human beings to become as powerful as they have? They harnessed the powers of nature. That's how we have made ourselves so powerful. While living their daily lives and trying to satisfy their needs always more and more efficiently, human beings gradually developed all branches of learning. Always wanting to satisfy their needs in a better and better way, eventually led human beings on to a path of endless discovery. It may not have been a conscious drive; it could have been an unconscious drive. In any case, human beings developed great knowledge of, for example, plants and animals; knowledge which was acquired for the purpose of satisfying their needs for food, clothing, shelter defense, transport. They learned how to build. They developed a knowledge of architecture while making use of wood, stone, and metal, and taking advantage of laws and forces infinitely more powerful than themselves. They developed a knowledge of physics, of chemistry, and so on. Therefore, starting from the simple, practical beginnings of a daily life existence, human beings developed the incredible knowledge that we possess today.

I haven't even talked about language and maths. Language and maths (which for me is actually the three branches of arithmetic, geometry, and algebra) are also part of the human story. We think of human beings as God's chief agent for creation—and by the way if you have the power to create you also have the power to destroy—but they couldn't have carried out that role, they couldn't have transformed the environment and built a supernature, had they not had language which permitted them to develop a group intelligence, as well as mathematics.

If the children can learn to appreciate how, starting from very simple beginnings, living in nature as part of nature only, human beings came to achieve what we have today, and also how we have benefited from all the work of all human beings who came before us, then the children will come to feel that gratitude to humanity that both Maria and Mario Montessori talk about. Yesterday we were talking about gratitude to nature, to God; today the emphasis is on gratitude to humanity. We can feel gratitude to all living human beings, from whom we receive so much and on whom we depend for their work; we can feel gratitude to all human beings of the past, from whom we've inherited so much and whose work still benefits us today.

Yesterday I gave the example of the alphabet. It's extraordinary to think that every time we make a little sign, that little sign goes back to over three thousand years ago. Did the Americans invent the alphabet? Did the British invent the alphabet? Did the Romans invent the alphabet? (We identify our alphabet as the Roman alphabet, don't we?) No, it goes right back to long before the Romans, and yet millions and millions of us are still using it. What difference did this particular invention make? An absolutely unbelievable difference. And the same thing is true for those numbers that we also inherited from so long ago and so far away. And what's amazing is to see the continuity, a continuity which is like a long chain of solidarity throughout time.

Montessori talks about these bonds of solidarity: If only we can see, then we can understand that we have all these bonds to human beings of the past. This understanding builds gratitude: without our having to preach; without our having to give sermons; without our having to say we should be grateful, we should say thank you. This kind of understanding also builds human solidarity. It's the kind of understanding and appreciation that we want these second-plane children to grow up with. Children feel a natural attraction to, and an interest in, what is extraordinary, what is magnificent; and they have a natural tendency to hero worship. All of this can be directed to humanity, instead of to some pop star or football star.

Perhaps I should finish with human solidarity, which is where I started. From a Montessori point of view, we want to help the children in their development; with this kind of approach to history, we do help the children in their development. The aim, the underlying aim that we always have to bear in mind whenever we work in history with the children, is human solidarity. Montessori says the whole point of exploring history is to help the children become aware of how we have become a *nazione unica*, a single nation of humanity, which means we are united with all the people of the past as well as with the people of the present; and our aim is therefore to have this sense of universal human solidarity blossom in our children. Then the children who grow and develop in this way will become adults who are builders and keepers of peace.

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Montessori Citizens: Continuing the Science!

Participants Needed for Montessori Research

Dr. Angeline Lillard and her research team at the University of Virginia are seeking participants for a study of people's lives and school histories, and they would be grateful for your participation in an anonymous online survey. It should take only 15-20 minutes and will help provide important information on whether and how school experiences might relate to life outcomes. Please forward to others (over 18 in North America & Canada) who might be able to participate. Participants who complete the survey and provide an email address will have the chance to win a drawing for a $125 Amazon gift card.

Please access the survey through this direct link:

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If you have any questions or concerns, please feel free to email us at later.outcomes.uva@gmail.com or call (434) 982-5368. Thank you in advance for assisting Dr. Lillard and her team with this invaluable research.

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The acceleration of technology and the complexity of changes that are driving our current society will define the future for today's children. As Montessorians, we have the knowledge and practice that addresses the development of the "whole person." Montessori education develops critical thinking, problem solving, and creativity all within a microcosm of a respectful, harmonious society, and thus prepares each individual to adapt to their own time, place, and culture.

This conference weaves together the understanding of technology and its impact on today's children with an exploration of the forces that keep us grounded in our humanity and connected to one another, leading to an understanding of the fundamental ways in which creativity, storytelling, and experiences in the natural world must inform our work with children at all stages of development.

"There is no description, no image in any book that is capable of replacing the sight of real trees, and all the life to be found around them, in a real forest. Something emanates from those trees which speaks to the soul, something no book, no museum is capable of giving."
- Maria Montessori,
From Childhood to Adolescence

Conference Location

Greater Tacoma Convention Center

Hotel Accommodations

Courtyard by Marriott Tacoma

"Technology that tears apart our common reality and truth, constantly shreds our attention, or causes us to feel isolated makes it impossible to solve the world's other pressing problems like climate change, poverty, and polarization. No one wants technology like that. Which means we're all actually on the same team: Team Humanity, to realign technology with humanity's best interests."

Center for Humane Technology

"How often is the soul of man – especially that of the child – deprived because one does not put him in contact with nature?" **Maria Montessori**

Register at montessori-namta.org

Conference Schedule

Thursday, April 4th

7-8pm Registration

Friday, April 5th

8:00 – 9:00am
Registration

9:00 – 10:15am
Keynote: Elise Huneke-Stone

10:15 – 10: 45am
Break

10:45am – 12:00 noon
Keynote: Max Stossel

12:00 noon – 1:30pm
Lunch

1:30 – 4:30pm
Breakout Sessions:

- **A.** Technology Strategies for School and Home
- **B.** Navigating Social Media Across the Planes of Development
- **C.** Integration: The Union of the Inner and Outer World in the Child from 3 to 6

2:45 – 3:15pm
Break

Please join us for a special evening of stories & poetry. Details to follow. Friday, 7:00 – 9:30pm

Saturday, April 6th

8:00 – 9:00am
Coffee

9:00 – 10:15am
Keynote: Jay O'Callahan

10:15 – 10: 45am
Break

10:45am – 12:00 noon
Keynote: Jim Robbins

12:00 noon – 1:30pm
Lunch

1:30 – 4:30pm
Breakout Sessions:

- **A.** Storytelling Methods for Teachers
- **B.** The Power of Nature to Inspire and Guide Our Lessons for the Second Plane
- **C.** Creativity and Self-Expression: An Adolescent Model
- **D.** Creative Expression and the Human Tendencies at the Primary Level

2:45 – 3:15pm
Break

Sunday, April 7th

8:00 – 9:00am
Coffee

9:00 – 11:00am
Closing Discussion – Tying the Past to the Digital Age