Massimo Pigliucci (right) brought 196 to realize that heredity is not simply a matter of evolutionary questions. Researchers have come to realize that heredity is not simply a matter of evolution. Pigliucci is the headliner this week at a small conference in Altenberg, Austria, “promises to be far more transformative for the world” than the 1969 music festival, Mazur wrote online in March for Scoop.co.nz, an independent news publication in New Zealand.

That hyperbole has reverberated throughout the evolutionary biology community, putting Pigliucci and the 15 other participants at the forefront of a debate over whether ideas about evolution need updating. The mere mention of the “Altenberg 16,” as Mazur dubbed the group, causes some evolutionary biologists to roll their eyes. It’s a joke, says Jerry Coyne of the University of Chicago in Illinois. “I don’t think there’s anything that needs fixing.” Mazur’s attention, Pigliucci admits, “frankly caused me embarrassment.”

Yet Pigliucci and others argue that the so-called modern synthesis, which has guided evolutionary thought and research for about 70 years, needs freshening up. A lot has happened in the past half-century. DNA’s structure was revealed, genomes were sequenced, and developmental biologists turned their sights on evolutionary questions. Researchers have come to realize that heredity is not simply a matter of passing genes from parent to offspring, as the environment, chemical modification of DNA, and other factors come into play as well. Organisms vary not only in how they adapt to changing conditions but also in how they evolve.

Evolution is much more nuanced than the founders of the modern synthesis fully appreciated, says Pigliucci. That doesn’t mean that the overall theory of evolution is wrong, as some intelligent design proponents have tried to assert using Mazur’s story as support, but rather that the modern synthesis needs to better incorporate modern science and the data revealed by it. More than genes pass on information from one generation to the next, for example, and development seems to help shape evolution’s course. “Many things need fixing,” emphasizes one invited speaker, Eva Jablonka of Tel Aviv University in Israel. “I think that a new evolutionary synthesis is long overdue.”

Modern tradition

The modern synthesis essentially represents a marriage of the 19th century concept of evolution with Mendelian genetics, which was rediscovered at the beginning of the 20th century; the birth of population genetics in the 1920s added to the intellectual mix. By the 1940s, biologists had worked out a set of ideas that put natural selection and adaptation at evolution’s core. Julian Huxley’s 1942 book, Evolution: The modern synthesis, brought together this work for a broad audience.

Simply put, the modern synthesis holds that organisms have a repertoire of traits that are passed down through the generations. Mutations in genes alter those traits bit by bit, and if conditions are such that those alterations make an individual more fit, then the altered trait becomes more common over time. This process is called natural selection. In some cases, the new feature can replace an old one; in other instances, natural selection also leads to speciation.

However, several concepts have arisen since then that make the modern synthesis seem too simplistic to some, Pigliucci among them. In a 2007 Evolution paper, he called for the development of an “extended evolutionary synthesis.” His plea coincided with a similar one made that year by Gerd Müller, a theoretical biologist at the University of Vienna. Together, with support from the Konrad Lorenz Institute for Evolution and Cognition Research in Altenberg, they organized this week’s conference, inviting many who share the view that the modern synthesis is incomplete. “What’s happening now in evolutionary theory is as exciting and foundational as during the early days,” says David Wilson of Binghamton University in New York, another attendee.

Beyond genes

Insights from ecology, developmental biology, and genomics in particular are nudging evolutionary biology away from a focus on population genetics—how the distribution of genes changes across groups of individuals—and toward an understanding of the molecular underpinnings of these changes. Better family trees that give researchers greater confidence about the relatedness among organisms have helped promote a credible, comparative approach to these mechanisms, says invite Günter Wagner, an evolutionary developmental biologist at Yale University.

Some studies, for example, indicate that development constrains evolution. From the modern synthesis perspective, Wagner explains, “the body plan is a historical residue of evolutionary time, the afterglow of the evolution...
lutionary process” such that more closely related organisms share more features. The alternative view, he says, is that “body plans have internal inertia,” and evolution works around this stability.

This perspective fits in well with that of Stuart Newman, another invitee to the conference. A developmental biologist at New York Medical College in Valhalla, Newman and Müller have focused on physical processes that guide how cells organize limbs, livers, hearts, and other tissues. The stickiness, elasticity, and chemical reactions within and between cells, for example, all influence where cells wind up in an organism. The duo thinks these processes helped define early multicellular life, a time when genetic systems were still quite primitive and body shapes were presumably more plastic than now.

Their work suggests that body plans with interior spaces, segments, appendages, and multiple layers of tissue are inevitable. That’s “heresy for the modern synthesis but inescapable if you incorporate physics into the picture,” says Newman. Studies of development that suggest how evolution proceeded—the so-called evo-devo approach—have yielded other insights, among them that genes and proteins are arranged in networks that have their own set of properties. “There are lots of interdependencies that allow only certain patterns of evolution to happen,” says Wagner.

Much like networks, “regulation” is a new buzzword in biology circles; yet it’s another concept virtually ignored in the modern synthesis. Scientists now grasp that gene activity, RNAs, and proteins are all under regulatory controls and that shifts in those controls likely drive evolution as much as traditional gene mutations that alter a protein’s form. Harvard University’s Marc Kirschner, for example, contends that organisms have long possessed “core” components—the machinery for energy metabolism, pattern formation during development, making cytoskeletons, or cell signaling—that have persisted relatively intact through time. But he proposes that genetic changes that alter when and where in the developing body these components are used have helped create modern diversity.

Wagner thinks that by virtue of the breadth of genes they influence, transcription factors may be central to the type of evolutionary shifts Kirschner proposes. Changing the regulation of a few factors, even one, could help coordinate the systemic changes needed to make a new trait, helping to ensure that larger muscles coevolve with bigger jawbones for a more powerful bite, for example. Bottom line: “New traits contain very little that is new in the way of functional components, whereas regulatory change is crucial,” Kirschner and John Gerhart of the University of California, Berkeley, wrote in a supplement to the 15 May 2007 issue of the Proceedings of the National Academy of Sciences.

The modern synthesis also doesn’t take into account epigenetics. A small chemical modification of a DNA base—the addition of a methyl group, for example—can turn a gene off or on as easily as a mutation. Molecular biologists have long known about such epigenetic effects, but only recently have they demonstrated that methylation tags and other epigenetic marks that silence or activate genes can travel from one generation to the next. That potentially creates a “bewildering increase in the complexity of the entire inheritance system,” Pigliucci asserted in his 2007 call to arms.

Certain environmental conditions, such as diet during gestation, can alter the epigenetic patterns of the resulting offspring, and new traits that result can last for generations, says Jablonka, who has been striving to get recognition for this mode of inheritance for years. For example, in a study conducted several years ago, pregnant mice injected with an endocrine disrupter gave birth to males with reduced fertility, whose subsequent sons, grandsons, and even great-grandsons were likewise affected. Each generation had inherited the same altered methylation pattern of DNA (Science, 3 June 2005, p. 1466). “It’s beginning to be accepted that [epigenetics] may actually have something to contribute to evolution,” says Jablonka.

She argues that because these chemical modifications change how tightly wound DNA is, they also influence other properties of a genome that are relevant to evolution. The coiling of a DNA strand, she points out, can alter the rate of mutation, the ease by which mobile elements can move around, the duplication of genes, and even how much gene exchange occurs between matching chromosomes.

Beyond reason?

As the Altenberg 16 seek to modernize the modern synthesis, other unconventional ideas will be on the table. One is evolvability, the inherent capacity of an organism or a population, even a species, to respond to a changing environment. Introduced about 20 years ago, the concept can help explain why certain groups of organisms readily and rapidly diversified. Consider vertebrate toes: Amphibians have a wider range in digit number than, say, reptiles, which may indicate that the former are more evolvable for that trait, Pigliucci points out. But the question remains whether natural selection favors more evolvable organisms. If the idea of evolvability wasn’t radical enough, a few researchers have proposed that organisms can stock up mutations whose effects manifest themselves only when the right circumstances arise.

Both ideas have their skeptics. “I don’t believe organisms have a closet where they maintain all this genetic variation,” says Douglas Schemske, an evolutionary biologist at Michigan State University in East Lansing. Even among those coming to Altenberg, there’s far from universal agreement. Wagner finds epigenetic inheritance hard to swallow. “I haven’t been convinced,” he says. And some outside the Altenberg 16 don’t see what all the fuss is about. “I’m happy” with the modern synthesis, says George Weiblen, an evolutionary biologist at the University of Minnesota, Minneapolis. Others note that some of the items on the meeting’s agenda, such as the role of plasticity in looks and behavior in evolution, have fallen in and out of favor for decades. “It’s like selling old wine in new bottles,” says Thomas Flatt of Brown University.

But these criticisms don’t faze Altenberg’s organizers. The modern synthesis emerged from at least a decade’s worth of discussions. “The crucial point of the workshop is bringing these concepts together,” says Müller. And no one truly expects a scientific Woodstock. “Woodstock was an immensely popular event celebrating a new musical mainstream,” says Newman. “I imagine this will be more like a jam session circa 1962.”