The Scientific Consensus on When a Human's Life Begins

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ABSTRACT: Peer-reviewed journals in the biological and life sciences literature have published articles that represent the biological view that a human's life begins at fertilization ("the fertilization view"). As those statements are typically offered without explanation or citation, the fertilization view seems to be uncontested by the editors, reviewers, and authors who contribute to scientific journals. However, Americans are split on whether the fertilization view is a "philosophical or religious belief" (45%) or a "biological and scientific fact" (46%), and only 38% of Americans view fertilization as the starting point of a human's life. In the two studies that explored experts' views on the matter, the fertilization view was the most popular perspective held by public health and IVF professionals. Since a recent study suggested that 80% of Americans view biologists as the group most qualified to determine when a human's life begins, experts in biology were surveyed to provide a new perspective to the literature on experts' views on this matter. Biologists from 1,058 academic institutions around the world assessed survey items on when a human's life begins and, overall, 96% (5337 out of 5577) affirmed the fertilization view. The founding principles of the field Science Communication suggest that scientists have an ethical and professional obligation to inform Americans, as well as people around the world, about scientific developments so members of the public can be empowered to make life decisions that are consistent with the best information available. Given that perspective—and a recent study's finding that a majority of Americans believe they deserve to know when a human's life begins in order to make informed reproductive decisions—science communicators should work to increase the level of science awareness on the fertilization view, as it

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stands alone as the leading biological perspective on when a human's life begins.

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1. Introduction

A recent national poll suggested that 38% of Americans believe a human's life begins at fertilization ("the fertilization view").[1] Another recent national poll reported that 46% of Americans recognize the fertilization view as a "biological and scientific fact", and 45% view it as a "philosophical or religious belief".[2] While Americans' views on when a human's life begins have been assessed in numerous polls in recent years, there is scant evidence of experts' opinions on this matter. This form of inquiry—assessing a factual dispute by surveying those with the relevant expertise—has been prominent in the debate about anthropogenic climate change,[3,4] but it has yet to be used to assess a large sample of relevant experts' views on when a human's life begins.

Two small-scale studies have been conducted to assess experts' views on this matter: in 1967, researchers surveyed public health professionals,[5] and in 2008, researchers surveyed professionals working in the *in vitro* fertilization field.[6] In both studies, fertilization was the most common view held by the experts: 35% of public health professionals (27 out of 76) and 26% of IVF professionals (67 out of 255) affirmed the fertilization view. However, given the scientific literature's recognition of the fertilization view, it is surprising that it has been affirmed by a plurality of Americans and experts, rather than a majority.

A recent review of the abstracts of peer-reviewed journals in the biological and life sciences literature reported that dozens of journals have published articles containing statements that affirm the fertilization view.[7] Since journals publish these statements without explanation or citation, it suggests that researchers, reviewers, and journal editors seem to accept the fertilization view as a well-known and well-accepted biological observation. As previewed in Table 1 below, efforts to compile citations to peer-reviewed articles that contain such statements have continued[8]—these articles can be categorized based on how explicitly they represent the fertilization view.

Table 1. Peer-reviewed journals that represent the fertilization view.

A. Fertilization marks the beginning of a human's life

1. *California Medicine*: "[T]he scientific fact, which everyone really knows, that human life begins at conception."[9]
2. *Australian and New Zealand Journal of Obstetrics and Gynaecology*: "The time of our conception is when we are most vulnerable to survival and growing as a healthy human being."[10]

3. *Trends in Cell Biology*: "Most readers of this review originated from a sperm-egg fusion event."[11]
4. *Reproduction*: "Human life begins with sperm and oocyte fusion."[12]

B. Fertilization marks the beginning of a new individual

5. *Frontiers in Cell and Developmental Biology*: "Fertilization is a key process in biology to the extent that a new individual will be born from the fusion of two cells."[13]
6. *Journal of Assisted Reproduction and Genetics:* "[A] new individual is derived from the fusion of a single sperm and egg."[14]
7. *Cell and Tissue Research:* "[F]ertilization is the process by which male and female haploid gametes (sperm and egg) unite to produce a genetically distinct individual."[15]
8. *Nature Reviews Molecular Cell Biology:* "During fertilization of an egg with a sperm, the haploid genomes of each parent are unified to form the diploid genome of a new and unique individual."[16]

C. Fertilization marks the beginning of life

9. *Physiological Reviews*: "A proper dialogue between spermatozoa and the egg is essential for conception of a new individual in sexually reproducing animals. Ca(2+) is crucial in orchestrating this unique event leading to a new life."[17]
10. *Cell*: "Recognition between sperm and the egg surface marks the beginning of life in all sexually reproducing organisms."[18]
11. *Molecular & Cellular Proteomics*: "Sperm are remarkably complex cells with a singularly important mission: to deliver paternal DNA and its associated factors to the oocyte to start a new life."[19]
12. *Communicative & Integrative Biology*: "It is intuitive that fertilization-the start of life-involves communication between a sperm cell and an egg."[20]

D. Fertilization is the transmission of genes from parents to their children

13. *Science*: "Fertilization is the sum of the cellular mechanisms that pass the genome from one generation to the next and initiate development of a new organism."[21]
14. *Methods in Molecular Biology*: "As representatives of the 60 trillion cells that make a human body, a sperm and an egg meet, recognize each other, and fuse to create a new generation."[22]
15. *Animal Reproduction Science*: "In higher animals, the beginning of new life and transfer of genetic material to the next generation occurs in the oviduct when two distinct gametes cells unite resulting in the formation of a zygote."[23]
16. *Current Opinion in Genetics & Development*: "In mammals, a new generation begins when an oocyte is fertilized by a sperm to form a zygote."[24]

E. Fertilization marks the beginning of development and the life cycle

17. *Nature*: "The life cycle of mammals begins when a sperm enters an egg."[25]
18. *Molecular Neurobiology*: "Aging is a developmental process that begins with fertilization and ends up with death involving a lot of environmental and genetic factors."[26]
19. *Journal of Cellular Physiology*: "At the time of fertilization, an increase in the intracellular Ca(2+) concentration ([Ca(2+)](i)) underlies egg activation and initiation of development in all species studied to date."[27]
20. *Seminars in Cell and Developmental Biology*: "At fertilization, eggs unite with sperm to initiate developmental programs that give rise to development of the embryo. Defining the molecular mechanism of this fundamental process at the beginning of life has been a key question in cell and developmental biology."[28]

These statements vary in their framing of the fertilization view, as some specifically state that fertilization marks the beginning of a human's life and others generally state that fertilization marks the beginning of a new individual, a new life, or the life cycle

of an organism. Still, all of these statements represent the fertilization view since they directly or indirectly state that fertilization marks the point at which a male's spermatozoon (sperm) and a female's oocyte (egg) unite to form a genetically unique organism (zygote)—that a zygote with a human genome is a human since he or she would then be biologically classified as a member of the *Homo sapiens* species whose life has started on the developmental path that can continue through the zygotic, embryonic, fetal, infant, child, adolescent, and adult stages of the human life cycle. Thus, taken together, these statements suggest the fertilization view is common in the biological and life sciences literature.

In a recent study,[29] Americans were asked who among the following list of authorities is most qualified to determine when a human's life begins: biologists, philosophers, religious leaders, Supreme Court Justices, and voters. A large majority of the 4,107 Americans surveyed selected biologists (80%). When participants were asked why they selected biologists, 91% stated that they "view biologists as objective experts in the study of life". Thus, a study was designed to assess biologists' views on the ontogenetic starting point of a human's life.

2. Materials and Methods

Participation in the survey was sought from members of biology and life sciences departments of colleges, universities, and research institutes around the world. First, a list of academic institutions was generated from rankings of biology programs.[30, 31] Second, contact information for post-doctoral researchers, lecturers, professors, and professors *emeriti* was collected from the institutions' biology and life sciences departmental faculty webpages.

62,469 academic biologists were recruited through e-mail and 7,402 participated in the online survey (12% response rate). Of the participants, 5,577 biologists from 1,058 institutions provided analyzable data on operative questions. This response rate was comparable to a recent study that used professors' publicly available e-mail addresses to recruit them to participate in a survey on their views on controversial topics.[32] The demographics of the participants suggest the sample was representative of the population of academic biologists around the world.

A majority of the participants held a Ph.D. (95%), and most identified as male (63%) and non-religious (63%). Ideologically, a majority identified as liberal (89%) and pro-choice (85%). Previous studies have shown that 61% of biologists identify as atheist or agnostic[33] and that members of the academy are likely to hold liberal beliefs.[34] Thus, since there was no indication of non-response or self-selection bias, the sample's religious and ideological breakdowns suggest the sample was likely representative of the overall population of academic biologists. Overall, the sample comprised biologists from 86 countries.

2.1. Survey Questions

First, biologists were asked whether they view the question of when a human's life begins as a scientific matter. Participants were presented the question: "Which group

is most qualified to answer the question 'When does a human's life begin?'" They were then asked to select from the following five options: biologists, philosophers, religious leaders, Supreme Court Justices, and voters. The participants were also asked to assess Americans' selection of biologists as the most credible authority on the matter: "In a recent survey, a large majority of participants selected biologists as the group most qualified to answer the question 'When does a human's life begin?'. Do you agree that biologists are most qualified to define when a human's life begins?"

Since the fertilization view is the leading view among Americans,[1, 2] public health professionals,[5] and *in vitro* professionals[6]—and since it has been stated without explanation or citation in articles published in numerous peer-reviewed journals such as *Science*,[21] *Nature*,[25, 35, 36] and *Cell*[18]—survey items were designed to assess whether biologists affirm the fertilization view.

Participants were presented five statements (Q1-Q5) that represented various semantic framings of the fertilization view, and they were asked to affirm or reject the statements. Finally, they were presented an open-ended essay question on the biological perspective on when a human's life begins (Q6):

- **Question 1:** The end product of mammalian fertilization is a fertilized egg ('zygote'), a new mammalian organism in the first stage of its species' life cycle with its species' genome.
- **Question 2:** The development of a mammal begins with fertilization, a process by which the spermatozoon from the male and the oocyte from the female unite to give rise to a new organism, the zygote.
- **Question 3:** A mammal's life begins at fertilization, the process during which a male gamete unites with a female gamete to form a single cell called a zygote.
- **Question 4:** In developmental biology, fertilization marks the beginning of a human's life since that process produces an organism with a human genome that has begun to develop in the first stage of the human life cycle.
- **Question 5:** From a biological perspective, a zygote that has a human genome is a human because it is a human organism developing in the earliest stage of the human life cycle.
- **Question 6:** From a biological perspective, how would you answer the question "When does a human's life begin?"

As shown in Table 1 above, peer-reviewed journals' statements that represent the fertilization view vary in how explicitly they state that a human's life begins at fertilization. These statements (Q1-Q5) similarly varied in their explicitness. Q1 and Q2 reference the beginning of a new organism, Q3 references the beginning of a new life, and Q4 and Q5 explicitly reference the beginning of a human's life. Some statements focused on mammals (Q1-Q3) and others focused on humans (Q4-Q5); while some were in the form of a declarative statement (Q1-Q3), others took the form of an argument (Q4-Q5); however, all fundamentally represented the view that fertilization marks the beginning

of a human's physical existence as an organism with a human genome who is developing in the human life cycle.

3. Results

3.1. Assessments of Who is Most Qualified to Determine When a Human's Life Begins

As shown in Figure 1 below, 64% of participants (2395 out of 3773) selected biologists as the group most qualified to answer the question "When does a human's life begin?", 23% selected philosophers (865 out of 3773), 1% selected religious leaders (53 out of 3773), 4% selected Supreme Court Justices (135 out of 3773), and 9% selected voters (325 out of 3773). In a separate measure, 68% of participants (2365 out of 3457) agreed with Americans' selection of biologists as the group most qualified to determine when a human's life begins, and 32% disagreed (1092 out of 3457). These data suggest that biologists do not only view experts in biology as most qualified to make this determination—they primarily view the question of when a human's life begins as a matter of biology.

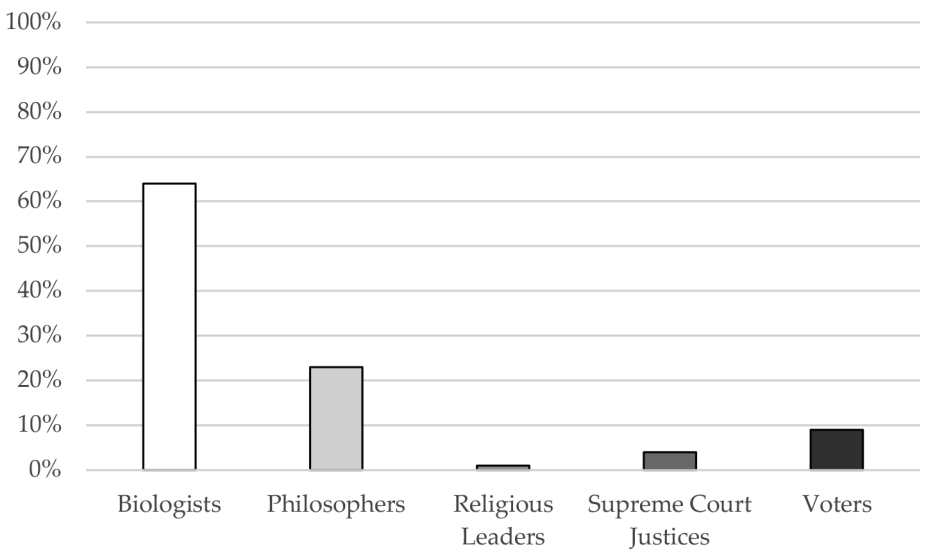

Figure 1. Percentage of biologists who selected different authorities in response to a question on who is most qualified to determine when a human's life begins.

3.2. Assessments of the Fertilization View

The statement in Q1 was affirmed by 91% of participants (4555 out of 4993). The statement in Q2 was affirmed by 88% of participants (3984 out of 4510). The statement in Q3 was affirmed by 77% of participants (3153 out of 4078). The statement in Q4 was affirmed by 75% of participants (2500 out of 3334). The statement in Q5 was affirmed by 69% of participants (2744 out of 3980). For a comparison of these affirmation rates, see Figure 2 below.

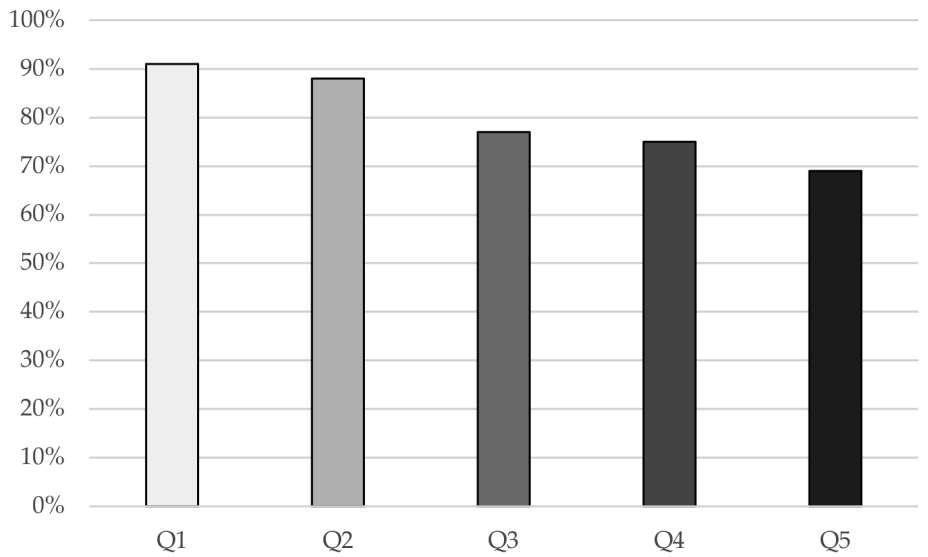

Figure 2. Percentage of biologists who assessed and affirmed the five statements that represented the fertilization view.

As shown in Figure 3 below, of those who assessed at least one of the five statements, 96% of participants affirmed at least one statement (5337 out of 5577) and 4% did not (240 out of 5577). Further, of those who assessed multiple statements, 96% affirmed at least one (4463 out of 4650) and 85% affirmed at least half of the statements they assessed (3936 out of 4650).

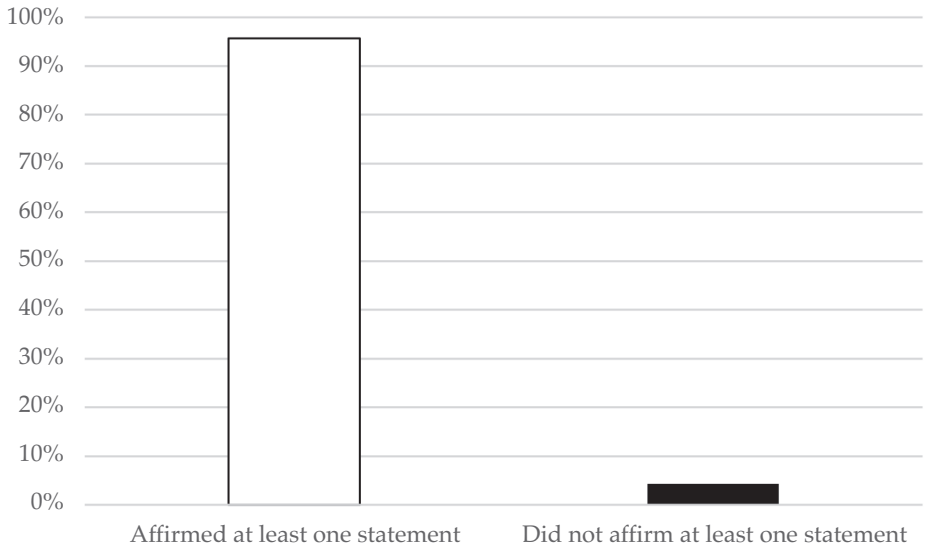

Figure 3. Percentage of biologists who assessed and affirmed at least one statement (Q1-Q5), and the percentage of biologists who assessed at least one statement but did not affirm any.

3.3. An Assessment of the Biological View on When a Human's Life Begins

Consistent with their affirmation rates of the fertilization view in Q1-Q5, Figure 4 below shows that 68% of biologists (1898 out of 2793) represented the fertilization view in response to Q6's open-ended essay question. Among the biologists who did not write about fertilization: 10% (268 out of 2793) represented some point between fertilization and viability (i.e., when a fetus can first survive outside of the womb), 10% (284 out of 2793) represented the viability view, and 12% (343 out of 2793) represented the view that a human's life begins at birth.

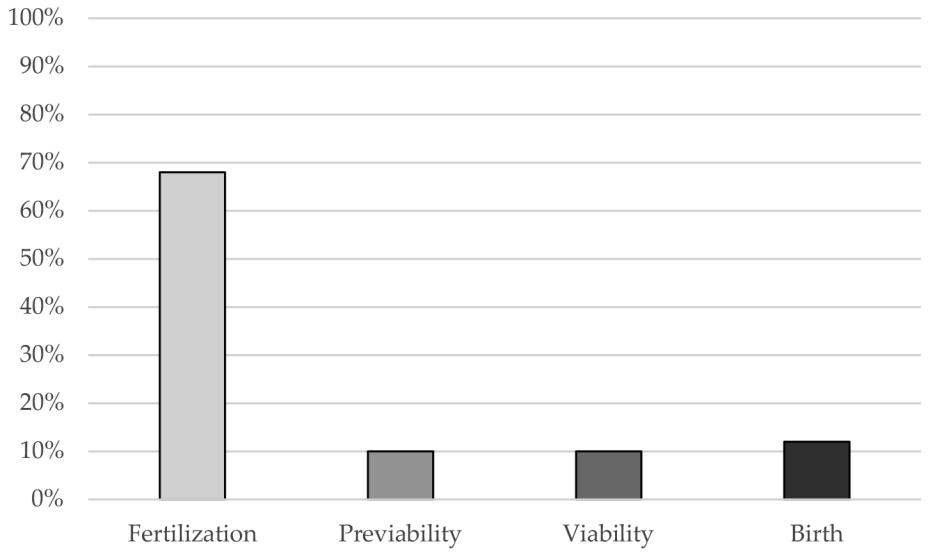

Figure 4. Percentage of biologists who represented different views in response to an open-ended essay question on the biological perspective on when a human's life begins.

The strictest measure of biologists' views assessed the responses of participants who answered each item consistently: (1) those who either affirmed each statement (Q1-Q5) and wrote about the fertilization view in response to the essay question (Q6), and (2) those who rejected each statement and wrote about some later point in development. As shown in Figure 5 below, there was a greater number of participants who consistently affirmed the fertilization view (97%; 1011 out of 1044) than those who consistently rejected the fertilization view (3%; 33 out of 1044).

4. Discussion

The use of the scientific method to assess experts' opinions on controversial topics has been effective in promoting science awareness of the effect of human behavior on climate change.[3, 4] Consensus cannot prove that the most commonly held view is true, but it can establish the leading view that can be recognized and relied upon as the best science available. However, a leading view can be most trusted if there is no reasonable

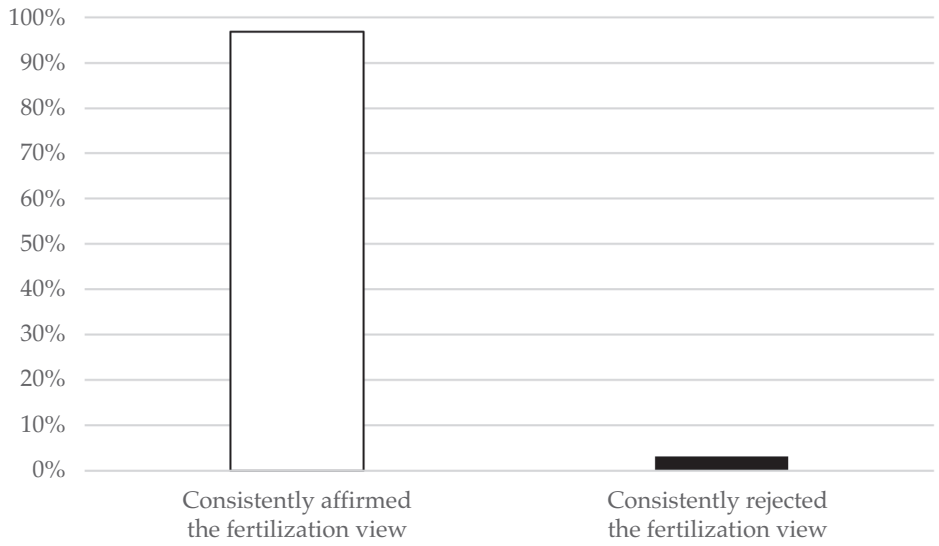

Figure 5. Percentage of biologists who responded consistently across all measures. Biologists who assessed and affirmed each statement (Q1-Q5) and represented the fertilization view in response to an open-ended essay question on when a human's life begins (Q6), and biologists who assessed and rejected each statement and represented some point other than fertilization in response to the essay question.

expectation that the consensus is driven by experts' financial, political, ideological, or personal motivations.

For instance, in the case of anthropogenic climate change, climate scientists might have financial incentives to affirm that human behavior is causing global warming[37] (e.g., increased grant funding, better speaking engagements, and even lucrative job opportunities in the corporate and finance sectors.)[38] They might also have personal motivations to affirm it; discussions of global warming have made climate science research more prominent, and climate scientists have never been more important or had more of an impact on policy, the economy, and politics. However, in the present study, since 85% of the sample identified as pro-choice and the fertilization view is typically associated with those who identify as pro-life,[1, 2] there is no indication that the present study's results were affected by such bias.

Based on the totality of the biological and life sciences literature's recognition of the fertilization view,[8] principles of the modern genetics-based method of biologically classifying organisms,[39] and the data reported in the present study, the fertilization view stands alone as the leading biological view on when a human's life begins. Thus, using the common meaning of "consensus" (i.e., general agreement), one can reasonably conclude that there is a scientific consensus on the view that a human's life begins at fertilization. Simply put, fertilization marks the point at which a human begins his or her physical existence as a human organism developing in the human life cycle, so he

or she is then properly biologically classified as a human and a member of the *Homo sapiens* species.

Given the high levels of agreement on the fertilization view in the scientific community, the low levels of agreement among the American public suggest an issue of low science awareness on when a human's life begins. Since 96% of biologists affirm the fertilization view but only 38% of Americans do,[1] there seems to not only be a large expert/public opinion gap but perhaps the largest gap on any contentious issue.

The *Pew Research Center* recently analyzed various knowledge gaps between the American public and experts, and it found that the largest gap (51 points) between Americans (37%) and scientists (88%) was on whether it is "[s]afe to eat genetically modified foods."[40] However, as suggested by the results of the present study, the expert/public opinion gap on when a human's life begins is even larger (58 points), as Americans are less likely to affirm the fertilization view (38%) than scientists (96%).

Since polls on Americans' views are typically conducted in the context of the abortion issue, it is possible that Americans' affirmation rate of the fertilization view would be higher, and the expert/public opinion gap would be smaller, if such questions are asked in isolation from discussions about abortion—Americans who support abortion rights might be more likely to affirm the fertilization view if they are not primed to think about abortion. Thus, researchers seeking to directly assess this expert/public opinion gap should consider asking both Americans and biologists their views in a non-abortive context. Indeed, it is important to understand and address this gap, as the question of when a human's life begins is no trivial or purely academic matter.

Americans were recently surveyed on the importance of this question, and 76% of participants suggested that Americans deserve to know when a human's life begins so they can make informed reproductive decisions.[29] The burgeoning field of Science Communication promotes the precept that scientists have a responsibility to communicate scientific findings to members of the public who can then base their life decisions on the best information available.[41, 42] The field's principles suggest that scientists are responsible for communicating the leading scientific view on when a human's life begins to the public, as it would enable Americans to make reproductive decisions informed by biological knowledge.

Given the size and breadth of the international sample of biologists in the present study, its results represent strong support for the claim that there is a scientific consensus on the view that a human's life begins at fertilization. However, as with any study, follow-up studies should be conducted to replicate these findings, to further assess biologists' stances on the fertilization view, and to perhaps assess why some biologists rejected the fertilization view by arguing that, from a biological perspective, a human's life begins at birth. If this study's findings are confirmed, then the fertilization view can be promoted by scientists and shared with members of the public to ensure they are informed on the biological perspective on when a human's life begins, as this would empower them to make informed reproductive decisions.

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