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Bacillus cereus & Bacillus pumilus Harvested from a Copper Roof Inhibit the Growth of Other Microorganisms

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ABSTRACT
Bacteria growing under the effects of unique selective pressures have distinct adaptations allowing them to survive. Copper surfaces present challenges for bacterial survival because ions dissolve from the surfaces and disrupt cell membranes, thus inhibiting bacterial growth. In this study, the copper roof of Simons Hall in Collegeville, Minnesota was sampled for bacterial species during November 2018. Bacteria were isolated and grown in culture, and zones of inhibition were identified surrounding three of the bacterial colonies. Polymerase chain reaction (PCR) was used to identify two of the bacteria samples as *Bacillus cereus* and a third sample as *Bacillus pumilus*. *Bacilli* are large, rod-shaped, gram-positive bacteria commonly found in diverse environments. They are endospore-forming aerobes or facultative anaerobes. Initial experiments indicated that all three *Bacillus* strains had the ability to inhibit the growth of three environmental microorganisms. Results from growth curve experiments depicted inhibitory effects on environmental microorganisms at all stages of the growth curve, which is contrary to the prediction that the inhibitory behavior would appear at one specific period of the growth curve. Additional experiments involved plating isolates of *Bacillus cereus* and *Bacillus pumilus* with laboratory samples of *Pseudomonas aeruginosa, Streptococcus pneumoniae,* and *Listeria monocytogenes* to further understand the effectiveness of *B. cereus* and *B. pumilus* at inhibiting the growth of other microorganisms. These findings support previous studies and suggest that *Bacillus* are capable of inhibiting or killing other organisms. Further research will be conducted to illuminate the inhibitory mechanisms and identify potential therapeutic possibilities.

KEYWORDS
Bacteria; Copper; Resistance; Growth Curve; Inhibition; Bacillus; Bacteriocin; Antimicrobial Peptides

INTRODUCTION

Bacteria are capable of inhabiting a wide variety of environments; however, some factors present challenges for bacterial growth. For example, limited food or water, excessive competition, and specific ions present unique pressures that microorganisms may develop advantages to overcome. Specifically, copper ions dissolve from copper surfaces, which disrupt the cell membrane and cause the loss of membrane potential and cytoplasmic content. Further, reactive oxygen species (ROS), such as those generated by copper ions, degrade cytoplasmic and genomic DNA. Contact killing of microorganisms on copper was observed to occur at a rate of at least seven to eight logs per hour.[1] Thus, as an application of the common notion that copper surfaces exhibit antimicrobial properties, hospitals and laboratories have implemented the use of copper surfaces in an effort to eliminate possibilities for contamination or spread of unwanted microorganisms.[2]

Although copper has been studied extensively for its toxic effects, there are microorganisms with adaptations allowing survival on copper surfaces. These microorganisms may have a competitive advantage in situations where copper is implemented for its antimicrobial effects. For example, bacterial samples previously isolated from a copper mine environment included *Acidovorax, Acinetobacter, Bacillus, Brevundimonas, Stenotrophomonas, Kocuria, Roseomonas, Pseudomonas,* and *Bacillus* was the most abundant and diverse in this environment.[3] *Bacilli* are large, rod shaped, gram positive, and endospore-forming aerobes or facultative anaerobes. The formation of endospores allows their resistance to heat, cold, radiation, desiccation, and disinfectants, thus they are able to inhabit a variety of environments that would otherwise inhibit bacterial growth.[4] They are common environmental organisms and are often the source of contamination in media and specimens in laboratories.[5] *Bacilli* can be found in diverse environments such as in gastrointestinal tracts of animals and insects, as well as in aquatic environments, food, soil, vegetation and rocks.[6] *Bacilli* exhibit additional competitive abilities against antibiotics and are one type of bacteria that produce β-lactamase which enables them to grow in the presence of beta lactam drugs, such as penicllin.[7] Further, antibiotic resistant plasmids have been isolated from *Bacillus cereus.*[8]

Starvation in some strains of *Bacilli* activates processes that promote survival under nutritional stress, including the development of genetic competence, sporulation, synthesis of degradative enzymes, motility, and antibiotic production.[9] Antimicrobial peptides synthesized by bacterial ribosomes are commonly classified as bacteriocins. Bacteriocins are classified by size, shape, and whether or not they possess lanthionine (or β-methyllanthionine) residues.[10] Previously, a *Bacillus* bacteriocin displaying antimicrobial activity against both gram-positive and gram-negative bacteria was isolated and classified. The bacteriocin also displayed stability across wide ranges of temperature and pH. This phenomenon was proposed to be due to unusual amino acids in the antimicrobial substances. The mechanism of bactericidal action was reported to be pore formation on the bacterial cell membrane, thus compromising its integrity.[11]

Other investigators have shown the usefulness of *Bacillus* bacteriocins. For example, Subtilosin A was developed from *Bacillus subtilis* 168 bacteriocins and has bactericidal activity against some gram-positive bacteria that are pathogenic to humans.[12] *Bacillus* bacteriocins are also being investigated as toxic to other bacteria and results are being reported in human health fields including the control of pathogenic bacteria such as MRSA, *G. vaginalis*, and *C. difficile*.[13] In addition to studies evaluating the potential of *Bacilli* in producing antibacterial bacteriocins, there have been studies evaluating compounds that have toxic effects on protozoa and fungi. Bottone *et al.* described a compound produced by *Bacillus pumilus* that was able to inhibit spore germination and hyphal elongation in *Mucoraceae* and *Aspergillus*.[14]

The discovery of naturally synthesized antimicrobial compounds by *Bacillus* species has been ongoing and abundant. In this study, *Bacillus cereus* and *Bacillus pumilu*s were isolated from a copper roof. The roof was sampled as an attempt to identify bacteria able to thrive in an environment devoid of many life promoting properties. The isolated *Bacillus* species were surviving in the environment yet under the pressure of the copper surface. It was hypothesized that the bacteria isolated from the copper roof were able to produce an inhibitory molecule or compound, such as a bacteriocin, during a specific period of their growth that would allow them to prevent other bacteria from growing near them.

METHODS AND PROCEDURES

Isolation and Identification

Sterile cotton swabs were used to sample the copper roof of Simons Hall on the Saint John's University Campus in November 2018. The samples were then swabbed onto trypticase soy agar (TSA) plates and allowed to grow for one week at 20° Celsius (**Figure 1**). Three distinct colonies (initially labelled 1, 2, and 4) were isolated along with three nearby colonies (10, 11, 12) from the mixed culture plate and identified by 16s rRNA PCR.

16s rRNA Polymerase Chain Reaction

Pure cultures of the three bacterial species (1, 2, 4) were subject to PCR amplification using universal primers U341F and UA1406R that recognize an 1100bp segment of the 16s rRNA gene. PCR products were run on a 1.5% agarose gel and confirmed to be 1100 bp in length. PCR products were then purified (QIAquick PCR Purification Kit, QIAGEN), pre-mixed with the forward universal primer U341F and sent to GeneWiz (South Plainfield, NJ) for sequencing. FASTA files were then used in a BLAST and the ARB-SLIVA project aligner to identify the most likely genus and species of each organism. Bacterial samples 1 and 2 produced significant alignment for *Bacillus cereus* strain SKH 16S rRNA gene with a 99.60% identity (Accession KJ685393.1). Bacteria sample 4 produced alignment for *Bacillus pumilus* strain 17 16S rRNA gene with a 99.20% identity (Accession MK621233.1).

Antimicrobial testing

Following growth of the microorganisms on TSA, it was observed that some colonies were surrounded by clear zones of no growth (inhibition) suggestive of an ability to impact the growth of other microorganisms in a population (**Figure 1**). We identified samples 1, 2 and 4 as potentially having antimicrobial properties against samples 10, 11 and 12. To test this, TSA plates were simultaneously streaked with either 1, 2 or 4 at the center black line and at the smaller lines with 10, 11 or 12. These plates were then incubated at room temperature and checked for zones of inhibition two days later (**Figure 2**). This test was repeated as shown in **Figure 3** but with the difference that isolates 1, 2 and 4 were streaked on plates one day before 10, 11 or 12 or the opposite.

In a second experiment, the antibiotic capabilities of *Bacillus pumilus* (4) were tested by picking colonies using sterile toothpicks and inoculating 3 mL of Tryptic Soy Broth (TSB) overnight at 27 °C. The following morning, 150 µL of the culture was used to inoculate 50 mL of TSB in 250 ml Erlenmeyer flasks. Nine flasks (A-J) were then shaken at 150 RPM in a New Brunswick Scientific C25 floor shaker set at 27 °C. Lawns of environmental sample 12 were made on TSA plates at the same time as the overnight tubes were inoculated. At the times shown on the sample plates in **Figure 4a**, 25 µL from a given flask was pipetted onto the lawn using sterile pipette tips. Growth of the bacteria in the Erlenmeyer flask was monitored by measuring optical density at 600 nm using a Beckman Coulter DU640 ultraviolet/visible spectrophotometer.

In a third experiment (**Figure 5**), liquid inoculum of environmental microbe 12 was individually spread on TSA plates using sterile swabs in order to create a bacterial lawn. Immediately after inoculating the bacteria on the TSA plates 25 μL of *Bacillus cereus a* and *Bacillus cereus b* (1, 2) were added to each of the plates. This procedure was repeated with cultures of *Bacillus* at different stages in the growth curve, as described above. All bacterial cultures were used in these experiments immediately after recording the OD_{600} and agar plates were incubated at room temperature.

A fourth experiment involved plating isolates of *Bacillus cereus* and *Bacillus pumilus* with laboratory samples of *Pseudomonas aeruginosa, Streptococcus pneumoniae,* and *Listeria monocytogenes* to further understand the effectiveness of *B. cereus* and *B. pumilus* at inhibiting the growth of other organisms. Two sets of lawns were made for each *Bacillus* strain. The lawns were made by placing two sterile test tube caps upside down on the TSA plates about 1 inch apart. The lawn of the selected bacteria was then made around those caps. The circumference of the caps was marked on the plate as a reference. One set of lawns was made the day before *Bacillus* strains were plated and one set was made at the same time *Bacillus* strains were plated. On each plate, killer 1a/b (*B. cereus)* and killer 4a/b (*B. pumilus)* were plated in the spaces left by the test tube caps. Two tubes of each *Bacillus* strain were inoculated in tryptic soy broth (TSB). This was denoted as T_0. At T_0, 100 microliters (μL) of *Bacillus* was plated. The broth cultures of the *Bacillus* strains were shaken at 27 °C at 150 RPM and were taken out and plated at the two-hour intervals**.** All of the plates were left to grow overnight at 20 °C.

RESULTS

Saint John's University is set amid 2,700 acres of land in rural, Collegeville Minnesota. In November 2018 the copper roof of one of the academic buildings was sampled to obtain microorganisms that were able to survive in the presence of copper (**Figure 1**). Over twelve different types of colonies were observed on the TSA agar plates following incubation at 20 °C. Interestingly, there were obvious zones of inhibition apparent surrounding three of the colonies (**Figure 1**).

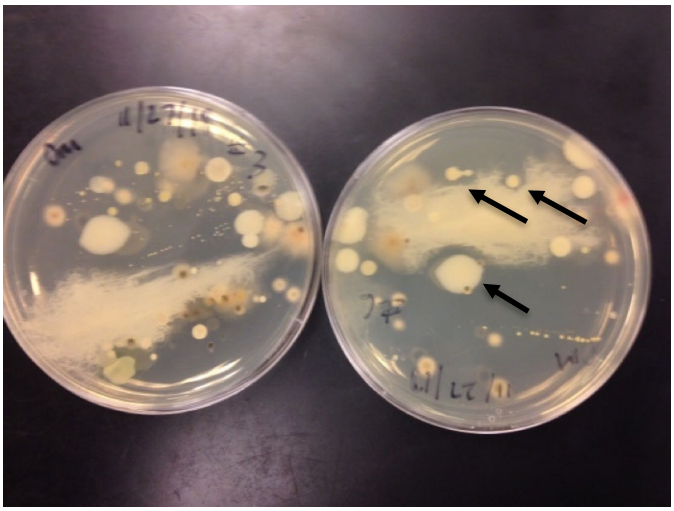


Figure 1. Microbial growth on TSA plates obtained by swabbing the copper roof of Simons Hall with sterile swabs. The diameters of the zones of inhibition around the top left, top right, and bottom colonies are 5.6 mm, 8.8 mm and 26.4 mm, respectively.

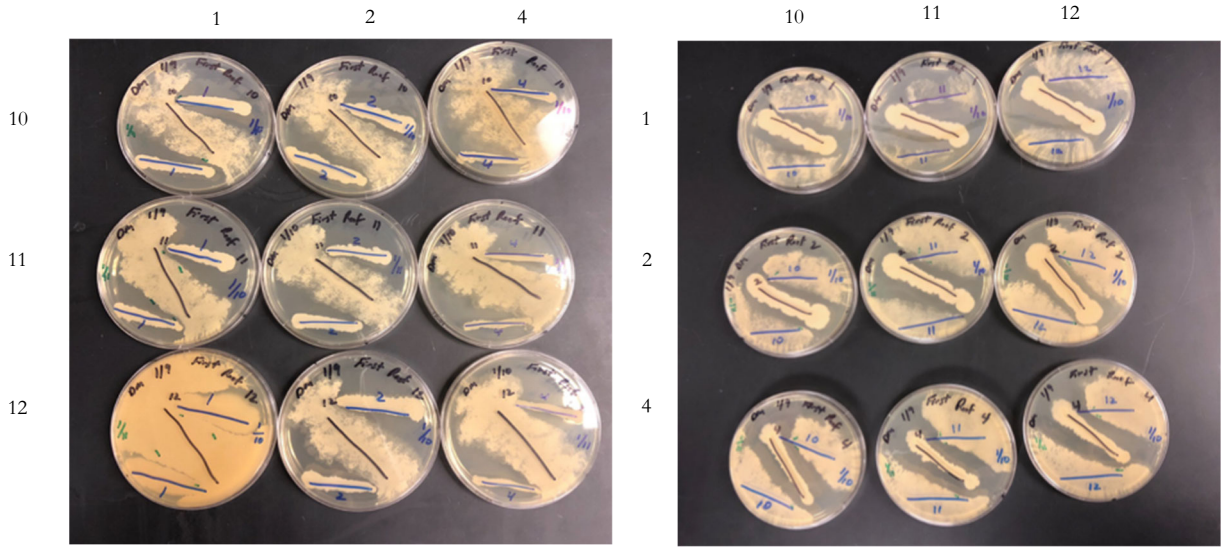
The three colonies that displayed zones of inhibition surrounding their growth were further characterized and identified as *Bacillus cereus a*, *Bacillus cereus b*, and *Bacillus pumilus*. To determine whether the growth inhibiting properties of these three species depended on the phase of the growth at which they were introduced to environmental microbes, *Bacillus cereus a*, *Bacillus cereus b*, and *Bacillus pumilus* (1, 2, and 4, respectively; **Figure 2**) were streaked simultaneously with the environmental microbes (microbes whose growth was inhibited and isolated from the same agar plates in **Figure 1**; 10, 11, 12). All three *Bacillus* species displayed patterns of inhibiting the growth of the environmental microbes with the *Bacillus pumilus* displaying the most potent antimicrobial activity with the largest zone of inhibition, 22.0 mm (**Figure 2 c).**

In order to determine if the *Bacillus* species could still produce antimicrobial compounds and inhibit the growth of already established and growing environmental microbes, the environmental microbes (10, 11, 12) were streaked diagonally across TSA agar plates and allowed to grow for 24 hours. The three *Bacillus* species were then introduced by streaking parallel lines on either side of the environmental microbes (**Figure 3a**). These data were compared to a similar experiment where the *Bacillus* species were first streaked diagonally across TSA agar plates, allowed to grow for 24 hours and then the environmental microbes were

introduced (**Figure 3b**). In both experimental designs, the *Bacillus* species displayed clear zones of inhibition around the environmental microbes.

(a) (b) (c)

Figure 2. *B.cereus* and *B.pumilus* inhibition of environmental microbes. Bacteria samples were streaked simultaneously (black lines) onto three TSA plates using a sterile cotton tip (a, b, c). Samples 1, 2, and 4 correspond to *Bacillus cereus a*, *Bacillus cereus b*, and *Bacillus pumilus* and were identified as inhibiting the growth of the unknown microbes 10, 11, and 12. Blue lines represent the inhibition of samples 1, 2, and 4 two days after plates were made. The zones of inhibition for **figures** a, b, and c are 15.4 mm, 16.5 mm, and 22.0 mm, respectively.



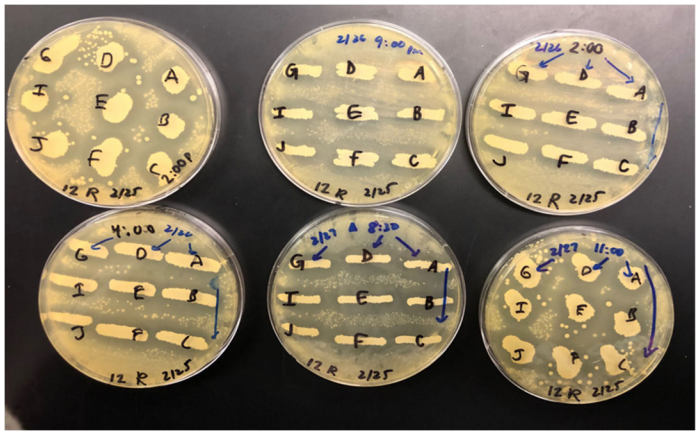
(a) (b)

Figure 3. Qualitative depiction of *Bacillus cereus* and *Bacillus pumilus* inhibition of environmental microbes when given a time advantage for growth. (a) Environmental microbes (10, 11, 12) were streaked on TSA agar plates one day before the introduction of *Bacillus cereus a*, *Bacillus cereus b*, and *Bacillus pumilus* (represented by lines 1, 2, and 4 respectively). (b) *Bacillus cereus a*, *Bacillus cereus b*, and *Bacillus pumilus* (1, 2, 4 respectively) were streaked on TSA agar plates one day before the unknown environmental bacteria (10, 11, 12). Numbers above each figure represent the cultures displayed in parallel lines. Numbers to the left of each **figure** represents the cultures displayed diagonally.

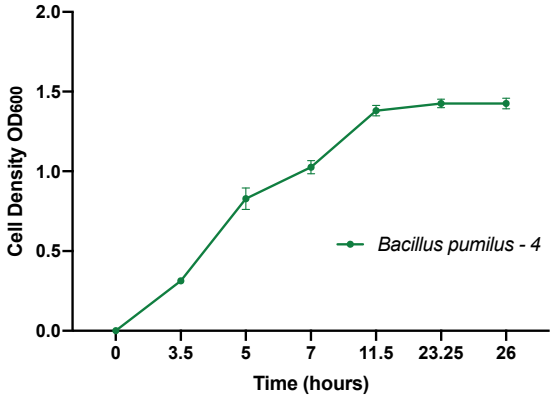
To specifically evaluate the antimicrobial properties of the proposed *Bacillus pumilus* bacteriocin, a series of flasks (A-J) were inoculated with *Bacillus pumulis* and at different time points were inoculated on a 24-hour lawn of environmental microbe 12. Each plate represents a different time (after inoculation in the flasks) at which the *Bacillus pumilus* was introduced to the lawn of environmental microbe 12 (**Figure 4a**). Zones of inhibition were observed throughout all nine isolates (A-J). Average zones of inhibition are recorded in **Table 1.** Antimicrobial properties indicated by the zones of inhibition were present for all inoculum sizes of *Bacillus pumilus.* (**Figure 4b**).

Time(hours)	3.5	5.0	7.0	11.5	23.25	26
Average Zone of Inhibition (mm)	19.0 ± 1.5	16.2 ± 3.7	10.5 ± 1.2	11.0 ± 1.9	13.4± 2.5	18.2 ± 1.8

Table 1. Average zone of inhibition(mm) for nine colonies of *B. pumilus* as a function of time grown in liquid culture before streaking onto TSA plates with unknown environmental microbe 12. Environmental microbe 12 was allowed one day of growth prior to streaking *B. pumilus* onto the plate. n=9



(a)



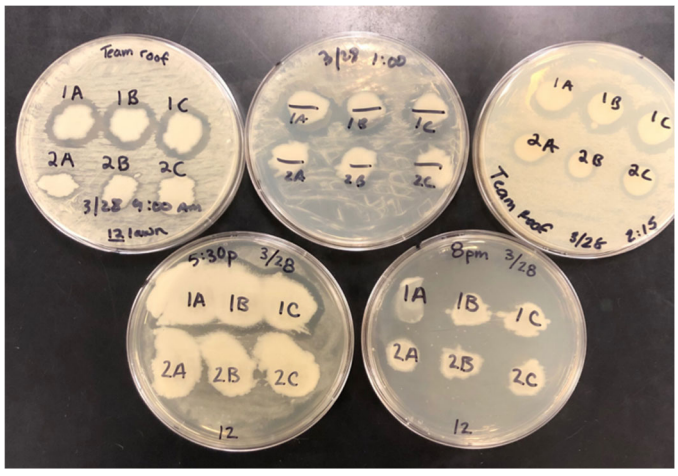
(b)

Figure 4. (a) *Bacillus pumilus* inhibition of environmental microbes. Environmental microbe (12) was inoculated onto TSA to make a bacterial lawn. One day later, *Bacillus pumilus* was inoculated onto the agar (represented by letters) at various stages of their growth curves (time points move from top left to lower right). The circular colonies were obtained because a localized sample was pipetted onto the plate and the line colonies were created when a sterile cotton swab was used to inoculate the *Bacillus*. (b) Bacterial cultures (n=9) were grown in TSB at 27 °C with shaking and OD_{600} measurements were taken at various time points. Average zones of inhibition in chronological order are 18.8 mm, 16.9 mm, 10.2 mm,10.3 mm,12.4 mm, and 15.8 mm.

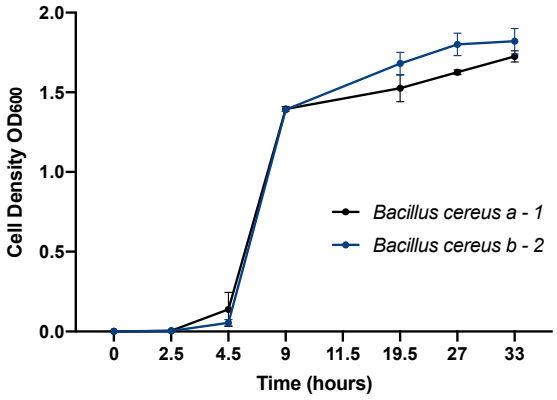
To determine the kinetics of when the antimicrobial compounds are produced by the *Bacillus* species, *Bacillus cereus a* and *b* were grown in liquid culture, and at various time points during the growth phase, (**Figure 5b**) were inoculated on a lawn of environmental microbe 12. The lawns were made at the same time that the *Bacillus* was introduced, so neither microorganism had a growth time advantage (no previous growth of environmental microbe 12 allowed). As demonstrated in **Figure 5a**, *Bacillus cereus* synthesized antimicrobial compounds and this inhibition, or the prevention of growth, of environmental microbe 12 seems to increase with time followed by a decrease at the final time point for *B. cereus*. Both *Bacillus cereus* samples (1, 2) prevented environmental microbe 12 from growing. Average diameters of the zones of inhibition in chronological order are recorded in **Table 2.**

Time(hours)	4.5	9.0	19.5	27.0	33.0
Average Zone of Inhibition (mm)	19.2 ± 0.46	16.4 ± 1.3	15.8 ±3.3	29.8 ± 2.8	15.4 ± 2.8

Table 2. Average zone of inhibition(mm) for nine colonies of *B. cereus* as a function of time grown in liquid culture before streaking onto TSA plates with unknown environmental microbe 12. Environmental microbe 12 was not allowed any extra time for growth prior to streaking *B. cereus* onto the plate. n=6



(a)



(b)

Figure 5. (a) *Bacillus cereus* inhibition of environmental microbes. Environmental microbe (12) was inoculated onto TSA to make a bacterial lawn. Immediately following, *Bacillus cereus* was inoculated onto the agar (represented by letters) at various stages of their growth curves. (b) Bacterial cultures (n=2) were grown in TSB at 27 °C with shaking and OD_{600} measurements were taken at various time points. Average diameters of the zones of inhibition in chronological order are 22 mm, 21.5 mm, 19.0 mm, 30.6 mm, and 15.6 mm.

To examine inhibitory properties of *Bacilli* against other common microorganisms, *B. cereus* and *B. pumilus* were plated with laboratory samples of *L. monocytogenes, P. aeruginosa.,* and *S. pneumoniae. B. cereus* produced zones of inhibition of 27.55 mm and 26.1 mm against *L. monocytogenes* when they were inoculated onto the plates on the same day. No zones were measurable when *Bacillus*±baci strains were plated a day before *L. monocytogenes*. Further, *B. pumilus* did not produce any zones of inhibition against *L. monocytogenes*. No zones of inhibition were measurable against *P. aeruginosa* for either strain of *Bacillus. B. cereus* produced a zone of 25.2 mm in diameter against *S. pneumoniae* when plated on the same day. No measurable zones were produced by *B. pumilus.*

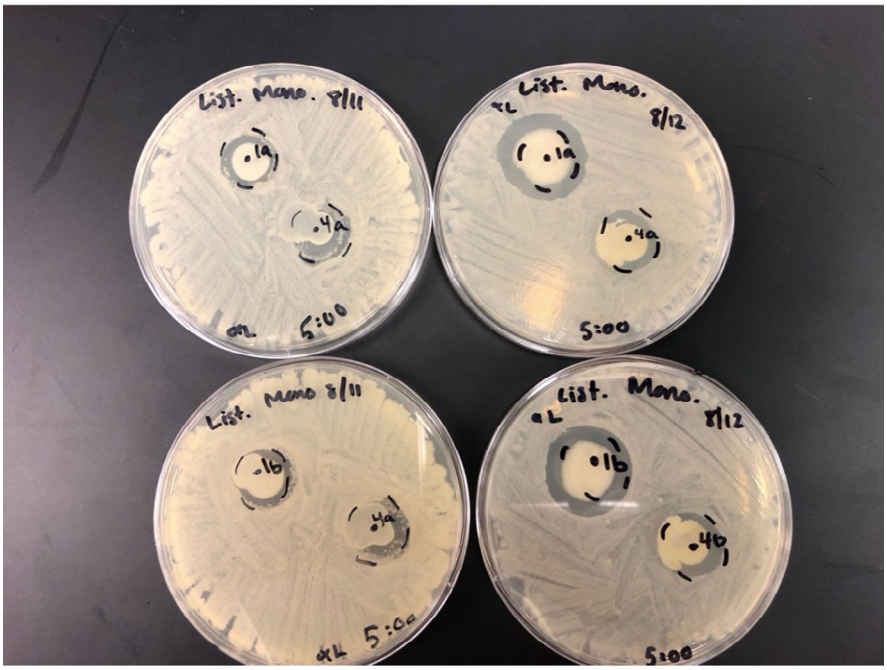


Figure 6. Differences in the zones of inhibition between *B. cereus (*1A, 1B) and *B. pumilus* (4A, and 4B) against *L. monocytogenes* at T_4 when *Bacillus* strains were plated the day before (8/11/2019) and the same day as (8/12/2019) *L. monocytogenes*. The large zones (27.55 mm and 26.1 mm, respectively) around 1A and 1B can be seen in the plates on the right.

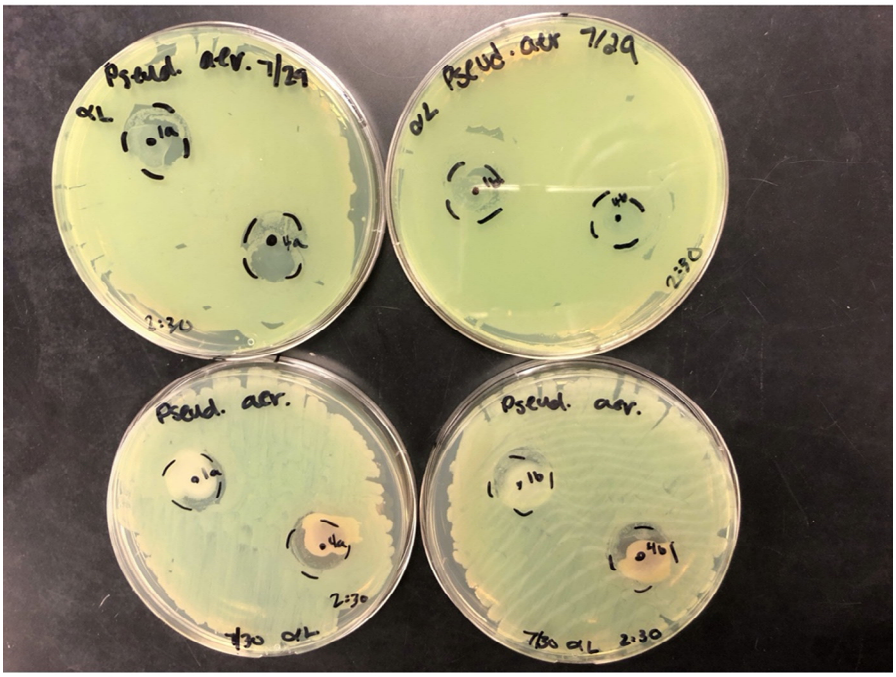


Figure 7. Plates of *B. cereus (*1A, 1B) and *B. pumilus* (4A, and 4B) with *P. aeruginosa* . No zones of inhibition are present. The two plates on the top are the ones when *Bacillus* strains were plated the day before *P. aeruginosa* and the two plates on the bottom are the ones when the *Bacillus* strains were plated on the same day as *P. aeruginosa.*

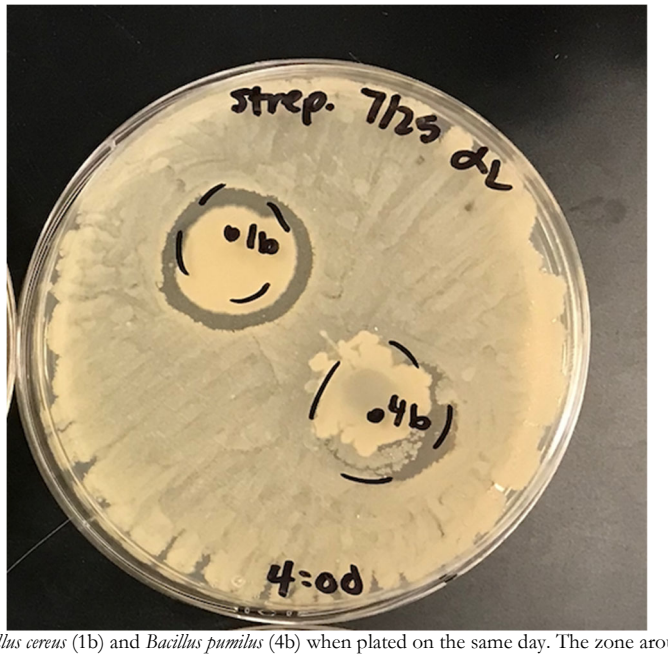


Figure 8. *S. pneumoniae* with *Bacillus cereus* (1b) and *Bacillus pumilus* (4b) when plated on the same day. The zone around 1B is 25.2 mm in diameter.

DISCUSSION

This study began with the idea of looking for microorganisms living in unusual or challenging environments. Related to this, it was hypothesized that any microorganism living in a challenging environment would benefit from the ability to produce antimicrobial compounds, thus providing a competitive advantage over other microorganisms inhabiting a similar location. The copper roof on Simons Hall provided an additional challenge to microorganisms that might have been deposited there by birds, snow, rain, or wind.

Our results suggest that environmental strains of *Bacillus cereus* and *Bacillus pumilus* possess the ability to produce toxic compounds that inhibit the growth of other microorganisms thus enhancing their own chances for survival. The zones of inhibition shown in **Figures 2-5** demonstrate that these isolated *Bacillus* strains are capable of producing these inhibitory compounds throughout their exponential growth phase. This would be quite beneficial to any microorganism competing with others – especially in environments with limited resources.

The production of bacteriocins or bacteriocin-like compounds by bacteria under selective pressure has also been previously documented and is well characterized in *Bacillus* and lactic acid bacteria (LAB). LABs are frequently isolated from nutrient-rich habitats that have soluble carbohydrates, low oxygen content, and available vitamins and proteins encouraging their survival.[15] *Lewus et al.* also determined that 80% of bacteriocin-producing LAB that were isolated from retail cuts of meat tested positive for a proteinaceous inhibitory substance that was specifically effective at inhibiting the growth of psychotropic pathogens.[16]

Bacteriocins isolated from *Bacillus* have a broad range of efficacy as they are capable of inhibiting both gram-negative and gram-positive bacteria, yeasts, and fungi.[13] Specifically, the five clinically recognized categories of antibiotics include bacterial peptidoglycan/cell wall disruption, protein biosynthesis, folate biosynthesis, DNA replication and transcription, and disruption of the bacterial membrane. Bacteriocins are known to inhibit four of these pathways (no known bacteriocins inhibit folate biosynthesis) as well as some novel ones including septum formation.[17] This behavior suggests it may be beneficial to harvest and identify the chemical compound(s) responsible for the toxicity in these *Bacillus* colonies. The identification of novel bacteriocins may have implications in both human health and control of infectious disease but also as natural alternatives for agriculture applications. For example, bacteriocin producing *Bacillus* strains inhibit intestinal pathogens and may be a promising probiotic species for humans and livestock. It was also reported that some *Bacillus* bacteriocins maybe able to control mastitis in dairy cows.[18]Additionally, these bacteriocins are suggested to have potential as a food preservative for dairy products.[19]

Initial experiments against a laboratory collection of microorganisms have begun. *Bacillus cereus* was effective in the inhibition of gram-positive *L. monocytogenes* and *S. pneumoniae,* while *Bacillus pumilus* was not effective against either. This suggests differences in

efficacy between the two strains of *Bacillus*. Neither strain inhibited *P. aeruginosa. B. cereus* was most effective when plated the same day as the other microorganisms, indicating that *B. cereus* does not need a time advantage for growth.

Future studies in our laboratory will be conducted to potentially identify inhibitory compound(s) that are produced by these specific strains of *Bacillus*. Extraction and purification of a bacteriocin from *Bacillus subtilis* through gel filtration and thin-layer chromatography has been conducted by other investigators. The isolated bacteriocin had bactericidal activity against some gram-positive and gram-negative bacteria.[12] It is predicted that similar methods could be used to purify the inhibitory molecules from the *Bacillus* species used in this study. Furthermore, once the inhibitory molecule(s) is isolated, it would be beneficial to subject it to mass spectrophotometry in order to determine what compounds contribute to the biochemical makeup of the inhibitory molecule(s). Additionally, it would be beneficial to determine the stability of these molecules across a range of pH conditions and temperatures in order to determine biochemical compatibility as a pharmaceutical or agricultural agent.

Bacilli have the ability to grow in environments that are toxic to other bacteria, such as copper, as well as the ability to inhibit the growth of gram-positive bacteria. The conclusion that *Bacillus cereus* and *Bacillus pumilus* synthesize inhibitory compounds during all stages of their growth cycles is foundational information that will be used to shape future studies. As the minimum inhibitory concentration of many antibiotics increases along with the rise in antibiotic resistance, it is imperative to study alternative approaches to these existing therapeutic methods.[20,21] Bacteriocins and conventional antibiotics act on different cell targets,[13] thus, bacteriocin applications may prove useful in the realm of therapeutic strategies and alternative antibiotics.

CONCLUSIONS

This study addresses foundational concepts of *Bacilli* bacteriocins. *Bacilli* are capable of inhibiting the growth of closely related environmental microbes, and the inhibitory behavior occurs at multiple phases of growth.

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ABOUT STUDENT AUTHORS

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PRESS SUMMARY

Copper presents unique challenges for bacterial growth; however, *Bacillus* harvested from a copper roof displayed inhibitory behavior against other bacterial colonies. It was predicted that an inhibitory mechanism was occurring at a specific stage of *Bacillus'* growth cycle, but this study illustrated that the inhibitory mechanism was occurring at all stages of bacterial growth. This is foundational information and will contribute to future studies involved in identifying and isolating the antimicrobial compound or molecule.

An Assessment of Sleep Duration and Determinants of Health in a Cross-Sectional Sample of Gynecologic Cancer Survivors in Los Angeles County

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ABSTRACT
Cancer survivors have an increased risk of treatment-related deficits in physical health and low health-related quality of life. In this cross-sectional study, a health questionnaire was mailed to women from the Los Angeles County Cancer Surveillance Program aged 45-70 and diagnosed with cervical, endometrial, or ovarian cancer in 2005-2014. Of the 5,941 surveys with valid postal addresses, 586 (10%) were completed and returned. The average age of respondents was 66 years old, and 36% identified as non-white. Non-white respondents were less likely to have a college degree (p<0.001), more likely to sleep for less than seven hours each night (p<0.001), experience bodily pain (p<0.001), and have a diagnosis of cervical cancer (p=0.002), when compared to white respondents. Health behaviors and determinants were examined across cervical, endometrial, and ovarian cancer cases. Cervical cancer survivors reported sleeping less than 7 hours per night, on average (p=0.015). Race was associated with sleep duration among endometrial (p=0.002) and ovarian (p=0.003) cancer survivors. Menopausal status was associated with the relationship between race and sleep duration (p<0.001). Depression was inversely related to sleep duration (p = 0.022) but was not associated with race, menopausal status, time since treatment, physical activity, or cancer type. Postmenopausal cervical cancer survivors reported a moderate concern about fall risk compared to their premenopausal counterparts (p=0.048). Physical activity levels increased as time since treatment increased (p=0.003) regardless of cancer type. Race, menopausal status, depression, and cancer type impacted the sleep duration.

KEYWORDS
Health Disparities; Sleep Duration; Depression; Gynecologic Cancers; Survivorship Care

INTRODUCTION

Cancer patients live more prolonged post-treatment than previous generations, as a result of technological advances that have increased early detection of cancer and improved the effectiveness of treatment plans.[1-3] Cancer survivors face a range of adjustments to their quality of life following cancer diagnosis and treatment, including possible unemployment, limitations in their daily living activities, and fear of cancer recurrence.[4] Previously published studies have shown that quality of life decreases in the time after treatment.[4,5] Lingering post-treatment symptoms have not been thoroughly investigated across cancer types or among diverse populations. Given the projected growth in cancer patients' numbers and racial diversity, increased attention must be paid to cancer survivors' quality of life.[2] This study analyzes three interconnected determinants of health-related quality of life (H.R.Q.O.L.) - physical activity, depression, and sleep duration - to highlight possible gaps in cancer survivorship care that need attention.

Physical Activity

Previous studies have analyzed the delivery format and the benefits of physical activity for cancer survivors. For example, home-based intervention for gynecologic cancer survivors that combined weekly exercise prescriptions coupled with either in-person or telephone counseling was highly successful compared to single format interventions.[6] The beneficial impact of the combined format extended to both the psychological and physical domains of health. A second study that focused on a combined format by Yun et al. noted that an exercise intervention program implemented with health education, leadership, and coaching on physical activity and dietary habits, and distress management led to improved quality of life. The intervention group in the Yun et al. study reported a decrease in anxiety and distress compared to the control group and an increase in the confidence to make health behavior changes.[7] Additional studies of exercise interventions with cancer survivors have reported reductions in perceived aches and pains and improved performance on fitness tests.[8,9]

Despite the practical benefits of physical activity, barriers to participation exist across socioeconomic status (S.E.S.), and race and many survivors exhibit a low motivation to participate. The most frequently reported barriers among all cancer survivors included competing time commitments between work and personal recreation and treatment-related limitations such as physical discomfort or fatigue.[10-13] Cost of gym memberships or exercise class participation was a reported barrier for survivors from lower S.E.S. backgrounds but was not concretely associated with race alone.[14] Family caregiving demands, transportation to exercise facilities and neighborhood availability of exercise spaces, health literacy, and patient-provider communication regarding survivorship care plans are mentioned more frequently among subgroups of non-white and lower S.E.S. cancer survivors.[14-16]

A few targeted interventions have been developed to begin to address these health disparities. A tailored exercise program was designed by Stewart et al. for African-American women to intervene on disproportionate endometrial survivorship among racial minorities.[17] The intervention acknowledged a disparity in comorbidities and possible socioeconomic barriers by combining the exercise program with educational workshops on improving nutritional status at various income levels. A similar approach was implemented by Ross et al. on the relationship between lack of physical activity and socioeconomic status with endometrial cancer survivorship.[18] The study found physical activity to be lower among African-American women who lived in low S.E.S. areas. This subgroup also had significantly higher rates of obesity-related comorbidities, such as hypertension, diabetes, hyperlipidemia, and metabolic syndrome, in comparison to women from higher S.E.S. areas.[18]

In the absence of racial and socioeconomic disparities, cancer survivors of all demographic backgrounds are susceptible to low motivation to participate in social activities and health-promoting behaviors. Reported sentiments include feeling "too tired and "not well enough" or a complete "lack of interest" if they did not engage in exercise before the cancer diagnosis.[19] Feeling tired, experiencing pain, and being inactive also increase the likelihood of falls after cancer treatment, leading to fractures and disability.[20-22] Survivors can be hesitant to change their lifestyles if they do not view inactivity or fatigue as a threat to cancer survivorship and quality of life.[12,23] This underscores the Health Beliefs Model's importance and provides cues to action tailored to cancer survivors.

Depression and Sleep Disturbances

Depression is prevalent among gynecologic cancer survivors and is commonly associated with a lack of social support, perceived quality of life, feelings of loneliness and isolation, and cancer-specific stress and fear of recurrence.[24,25] The depressive symptoms that many cancer survivors exhibit may not reach the clinical diagnosis level, yet they still concern in regards to successful survivorship.[26] The pervasiveness of symptoms was examined in a study that focused on the quality of life among cervical cancer survivors. Nearly 63% of the sample size suffered from depression, while 50% suffered from anxiety.[27] This prevalence is concerning given the projected increase in the number of cancer survivors. Furthermore, reported symptoms could linger for up to ten years after treatment, and often include: feelings of isolation, irritability, fear of cancer recurrence, post-traumatic stress syndrome, and feelings of hopelessness.[26] Higher risk of depression is associated with lower socioeconomic status, lower employment levels, and fewer financial resources.[28]

Gynecologic cancer survivors experience a higher prevalence of fatigue and sleep disturbance, or insomnia, as compared to cancer-free adults.[28] The group of women studied by Westin et al. presented as either being unable to fall asleep or stay asleep during the night, with the issue being most pronounced for cervical cancer survivors. Depressive symptoms are commonly associated with sleep disturbances, which can, in turn, cyclically exacerbate depressive symptoms.[29] Given that fatigue and sleep disturbances are typical post-treatment experiences, the expectation of their occurrence often leads to an under-diagnosis of depression and anxiety among survivors.[28,29]

Higher rates of insomnia, accompanied by depressive symptoms, may reduce cancer survivors' overall quality of life.[26] One proposed solution is healthcare provider screening for these indicators of poor H.R.Q.O.L. earlier in the survivorship continuum. However, a study by Zhou et al. found that when survivors disclosed their battle with insomnia, healthcare providers did not have the training to provide an effective intervention or treatment plan.[30]

This study is designed to expand current knowledge of physical activity, fall risk, sleep disturbance, and depression as determinants of HRQOL among gynecologic cancer survivors. Analyzing these determinants with the inclusion of racial group identification, menopausal status, cancer type, and treatment characteristics should provide a clearer understanding of the potential interconnectedness among the determinants and across patient subgroups. This expanded knowledge base may help healthcare providers understand the scale and importance of identifying H.R.Q.O.L. deficits among cancer survivors and could inform the development of efficacious and meaningful interventions.

METHODS

Study Population and Data Collection

The study was approved by the Loyola Marymount University Institutional Review Board (LMU IRB 2014 S.P. 27 and LMU IRB 2015 S.P. 23) and the California Health and Human Services Agency Institutional Review Board (Protocol ID 14-02-1507) per the Helsinki Declaration of 1975, as revised in 1983, and the Declaration of the World Medical Association.

Gynecologic cancer survivors were identified using the Los Angeles Cancer Surveillance Program. An anonymous questionnaire was sent by mail to 6,516 gynecologic cancer survivors with addresses in Los Angeles County aged 45-70 and diagnosed with cervical, endometrial, or ovarian cancer between 2005-2014. A self-addressed and stamped return envelope was included with each mailed questionnaire so that recipients would not feel compelled to provide their personal information as the sender of the envelope and reduce potential financial barriers associated with purchasing an envelope or postage. Approximately 9% of the 6,516 questionnaires (n=575) were returned due to an incorrect address. Of the remaining 5,941 mailed questionnaires, 586 questionnaires (10%) were completed and returned.

Demographic variables included education, race, menopausal status, cancer type, treatment type, and time since the last treatment. Most questions had a closed structure to collect information about demographic characteristics, medical history, health behaviors, and H.R.Q.O.L. (please reference the Appendix). For education, race, menopausal status, and treatment type, respondents chose from predetermined options. Since the last treatment, cancer type and time were collected by respondents individually writing in the primary type of cancer they were diagnosed with and the month and year of their last treatment. H.R.Q.O.L. variables included a self-reported number of falls within the past year, perceived risk of falling, activity levels, depression, and sleep duration.

Data Analysis

Continuous and categorical data collected from the questionnaires were coded using Microsoft Excel and imported into S.P.S.S. (Version 26, Armonk, NY: I.B.M. Corp). Continuous and categorical variables were collapsed according to the analysis formats depicted in Table 4.

The American College of Sports Medicine guidelines were used to classify respondents' physical activity levels based on the recommendation of ≥150 minutes of physical activity per week. The sleep duration categorization was based on the recommendation that adults sleep at least 7 hours per night.[31] Sleep duration was measured by respondents indicating their average rate of sleep as "4 hours or less", "5-6 hours", "7 hours or more". Health behavior and quality of life questions were worded following validated closed-formats from the SF36 and NIH PROMIS instruments. The frequency of falling was measured by the recalled number of times fallen in the past twelve months.[32] Respondents evaluated their risk for falling by answering the statement, "I am at risk for falls" on a 5-point Likert scale, ranging from "strongly disagree" to "strongly agree." Respondents evaluated if they experienced "bodily pain" within the past 4-weeks by answering "none," "very little," "moderate," "quite a bit" and "severe." The same categorical scale was used by participants to evaluate depression. Participants indicated their comorbidities (past and present) from various conditions, including anemia, stroke, ulcer, hepatitis, emphysema, type 1, and 2 diabetes. The number of comorbidities was created by summation of self-reported conditions to provide a cross-sectional prevalence of general health burden among respondents.

T-tests and ANOVA of continuous variables and Chi-squared analysis of categorical variables were performed to examine relationships across cancer type, race, menopausal status, treatment type, and time since the last treatment. Noteworthy relationships were characterized using a p-value threshold of 0.05. In contrast, p-values greater than 0.05 and less than or equal to 0.10 were identified as suggested relationships for future analysis in a larger sample.

RESULTS

The demographics of the 6,516 registry enrollees were: 4,504 endometrial cancer (69%), 1,180 ovarian cancer (18%), and 832 cervical cancer (13%). The average age was 63 ± 6.7 years with the racial distribution: 73% white, 8% black, 11% Asian, and 33% of participants across all racial groups identifying as having Hispanic ethnicity. Concerning time since treatment, 14.5% of registry enrollees were treated < 1 year from the questionnaires' mailing. Fifty-one percent (51%) were 1-4 years from treatment, and 34.5% were five years or more from treatment.

The demographics of survey respondents are comparable to the registry enrollment demographics, except for identifying Hispanic ethnicity. This exception is likely due to the registry protocol of counting both race and ethnicity versus the consideration for this study of Hispanic as a unique category for individuals that do not identify racially as White, Black, American Indian, Asian/Asian Pacific, or Other.

The respondents' average age is 66.54 ± 2.6 years, with 65-69-year-olds making up 92% of the sample (**Table 1**). Approximately 36% identify as non-white, with that subgroup comprised mainly of those identifying as Hispanic (48%), Black/African-American (20%), and Asian/Asian-Pacific Islander (28%). Non-white respondents are less likely to have a college degree ($p<0.001$), more likely to sleep for less than seven hours ($p<0.001$), report having bodily, physical pain ($p<0.001$), and have a diagnosis of cervical cancer ($p=0.002$).

Characteristic	N	Non-white	White	*p*
Age				0.924
49-64 yrs old	34 (5.8%)	13 (6.2%)	21 (5.6%)	
65-69 yrs old	540 (92.2%)	193 (91.9%)	347 (92.8%)	
70 + yrs old	10 (1.7%)	4 (1.9%)	6 (1.6%)	
Missing	2 (0.3%)			
Race/Ethnicity				<0.001
American Indian	3 (0.5%)	3 (1.4%)	0 (0%)	
Asian/ Asian Pacific	60 (9.9%)	60 (28.3%)	0 (0%)	
Black	43 (7.1%)	43 (20.3%)	0 (0%)	
Hispanic	101 (16.7%)	101 (47.6%)	0 (0%)	
Other	5 (0.9%)	5 (2.4%)	0 (0%)	
White	374 (61.7%)	0 (0%)	374 (100%)	
Education level				<0.001
≤High School	98 (16.7%)	57 (26.9%)	27 (7.2%)	
Some college	117 (20.0%)	51 (24.1%)	81 (21.7%)	
College graduate	369 (63.0%)	104 (49.1%)	265 (71.0%)	
Missing	2 (0.3%)			
Menopausal status				0.096
Premenopausal	237 (40.4%)	96 (45.5%)	141 (38.4%)	
Postmenopausal	341(58.2%)	115 (54.5%)	226 (61.6%)	
Missing	8 (1.4%)			
Treatment Type				0.149
Chemotherapy	29 (4.9. %)	16 (8.1%)	13 (3.7%)	
Radiation	153 (26.1%)	54 (27.4%)	99 (27.8%)	
Surgery	1 (0.2%)	0 (0%)	1 (0.3%)	
Combination	360 (61.5%)	122 (61.9%)	238 (66.9%)	
Other	10 (1.7%)	5 (2.5%)	5 (1.4%)	
Missing	33 (5.6%)			
Time Since Treatment				0.050
< 1year	83 (14.2.%)	29 (19.7%)	54 (17.9%)	
1-4 years	177 (30.2%)	68 (46.3%)	109 (36.2%)	
≥ 5 years	188 (32.1%)	50 (34.0%)	138 (45.8%)	
Missing	138 (23.5%)			
Activity Level				0.077
< 150 minutes	288 (49.2%)	99 (46.7%)	199 (53.2%)	
≥ 150 minutes	298 (50.8%)	113 (53.5%)	175 (46.8%)	
Sleep Duration				<0.001
≤4 hours	40 (6.0%)	20 (9.6%)	20 (5.4%)	
5-6 hours	240 (41.0%)	107 (51.4%)	133 (35.8%)	
≥ 7 hours	300 (51.2%)	81 (38.9%)	219 (58.9%)	
Missing	6 (1.0)			

Cancer Type				0.002
Cervical	46 (7.8%)	25 (13.5%)	21 (6.2%)	
Endometrial	337 (57.6%)	123 (66.5%)	214 (63.5%)	
Ovarian	139 (23.7%)	37 (20.0%)	102 (30.3%)	
Other	64 (10.9%)			
Characteristic	**N**	**Non-white**	**White**	***p***
Fall recurrence				0.821
Nonrecurrent	494 (84.3%)	176 (86.7%)	318 (86.4%)	
Recurrent	73 (12.5%)	27 (13.3%)	46 (12.6%)	
Missing	19 (3.2%)			
Fall risk				0.118
Agree	167 (28.5%)	70 (34.7%)	97 (26.4%)	
Neutral	78 (13.3%)	25 (12.4%)	53 (14.4%)	
Disagree	324 (55.3%)	107 (53.0%)	217 (59.1%)	
Missing	17 (2.9%)			
Bodily Pain				<0.001
Yes	176 (30.7%)	124 (58.8%)	151 (41.0%)	
No	397 (69.3%)	87 (41.2%)	217 (59/0%)	
Physical Pain				<0.001
Yes	273 (47.4%)	127 (60.8%)	273 (73.8%)	
No	303 (52.6%)	82 (39.2%)	97 (26.2%)	
Depression				0.276
Yes	174 (30.1%)	69 (32.9%)	105 (28.5%)	
No	404 (69.9%)	141 (67.1%)	263 (71.5%)	
Comorbidities				0.869
0	111 (19.3%)	38 (17.9%)	75 (20.3%)	
1	158 (27.5%)	59 (27.8%)	100 (27.1%)	
2	129 (22.5%)	51 (24.1%)	80 (21.7%)	
3	83 (14.5%)	28 (13.2%)	56 (15.2%)	
≥ 4	93 (16.2%)	36 (17.0%)	58 (15.7%)	

Table 1. Demographic and health behavior characteristics of respondents.

Concerning fall risk and physical activity as potential concerns for cancer survivors, the respondents in this sample who identified as postmenopausal cervical cancer survivors reported a moderate concern about fall risk compared to their premenopausal counterparts (p=0.048). Physical activity levels increased as time since treatment increased (p=0.003) regardless of cancer type. There were no other remarkable associations between fall risk or physical activity for this study's sample population.

Cervical cancer survivors reported sleeping for less than 7 hours per night (p=0.015). In a stratified analysis of the menopausal status and sleep duration, cervical cancer survivors continued to report fewer hours of sleep than endometrial and ovarian cancer survivors. However, no significant differences were detected between the premenopausal and postmenopausal subgroups. Menopausal status is suggested as a potential modifier of the relationship between time since treatment and sleep duration (premenopausal p=0.066). However, the stratified analysis would benefit from a larger sample size. A relationship between menopausal status, race, and sleep duration was observed, with non-white postmenopausal survivors reporting ≤ 5 hours per night in comparison to white postmenopausal women (p<0.001).

Sleep duration differed across white and non-white respondents when examined within each of the three cancer type sub-groups (**Table 2**). Treatment type differed by cancer type (p<0.001), with chemotherapy as the prevalent treatment experienced by ovarian cancer survivors (86.2%) as compared to 28.4% of endometrial and 38.6% of cervical cancer survivors (data not shown). The treatment type was not significantly different in its effect as a modifier of the relationship between race and sleep duration

(**Table 2**). However, it did appear as if a stronger relationship between race and sleep duration was present among those survivors who experienced chemotherapy ($p<0.001$), as compared to those that did not report an experience with chemotherapy ($p<0.035$).

	Cervical		**Endometrial**		**Ovarian**	
Sleep Duration	**Non-White**	**White**	**Non-white**	**White**	**Non-white**	**White**
≤4 hours	4 (16.0%)	4 (19.0%)	11 (9.1%)	12 (5.7%)	4 (11.4%)	3 (2.9%)
5-6 hours	10 (40.0%)	11 (52.4%)	63 (52.1%)	75 (35.4%)	18 (51.4%)	30 (29.4%)
≥7 hours	11 (44.0%)	6 (28.6%)	47 (38.8%)	125 (59.0%)	13 (37.1%)	69 (67.6%)
		p =0.555 for sleep duration x race among cervical cancer cases		p =0.002 for sleep duration x race among endometrial cancer cases		p =0.003 for sleep duration x race among ovarian cancer cases
	Chemo		**No chemo**			
Sleep Duration	**Non-white**	**White**	**Non-white**	**White**		
≤4 hours	10 (11.9%)	7 (4.4%)	9 (8.3%)	12 (6.2%)		
5-6 hours	47 (56.0%)	51 (31.9%)	54 (50.0%)	71 (36.6%)		
≥7 hours	27 (32.1%)	102 (63.8%)	45 (41.7%)	111 (57.2%)		
		p <0.001 for sleep duration x race among those who received chemotherapy		p =0.035 for sleep duration x race among those who did not receive chemotherapy		
	Chemo		**No chemo**			
Sleep Duration	**Premenopausal**	**Postmenopausal**	**Premenopausal**	**Postmenopausal**		
≤4 hours	7 (7.1%)	10 (6.9%)	12 (10.2%)	9 (5.0%)		
5-6 hours	40 (40.4%)	58 (40.3%)	42 (35.6%)	81 (45.0%)		
≥7 hours	52 (52.5%)	76 (52.8%)	64 (54.2%)	90 (50.0%)		
		p = 0.999 for sleep duration x menopausal status among those who received chemotherapy		p = 0.107 for sleep duration x menopausal status among those who did not receive chemotherapy		

Table 2. Associations between race and menopausal status with sleep duration, stratified by cancer type and treatment type.

Duration									
≤4 hours	0 (0%)	3 (8.8%)	1 (3.0%)	3 (33.3%)	7 (6.4%)	1 (2.6%)	1 (5.0%)	8 (7.6%)	2 (4.8%)
5-6 hours	3 (60.0%)	17 (50.0%)	11 (33.3%)	3 (33.3%)	35 (32.1%)	11 (33.3%)	11 (55.0%)	45 (42.9%)	11 (26.2%)
≥7 hours	2 (40.0%)	14 (41.2%)	21 (63.6%)	3 (33.3%)	67 (61.5%)	21 (63.6%)	8 (40.0%)	52 (49.5%)	29 (69.0%)
			p = 0.339 for sleep duration x cancer type among those with TST < 1 year			p = 0.014 for sleep duration x cancer type among those with TST 1-4 years			p = 0.153 for sleep duration x cancer type among those with T.S.T. ≥5years
Sleep Duration	**Non-White**	**White**		**Non-White**	**White**		**Non-White**	**White**	
≤4 hours	3 (10.7%)	1 (1.9%)		4 (6.1%)	7 (6.5%)		6 (12.05%)	6 (4.3%)	
5-6 hours	18 (64.3%)	19 (35.2%)		30 (45.5%)	33 (30.6%)		29 (58.0%)	51 (37.0%)	
≥7 hours	7 (25.0%)	34 (63.0%)		32 (48.5%)	68 (63.0%)		15 (30.0%)	81 (58.7%)	
		p = 0.003 for sleep duration x race among those with TST < 1 year			p = 0.001 for sleep duration x race among those with TST 1-4 years			p = 0.639 for sleep duration x race among those with T.S.T. ≥5years	
Sleep Duration	**Pre-Meno-pausal**	**Post-Menopausal**		**Pre-Meno-pausal**	**Post-Menopausal**		**Pre-Meno-pausal**	**Post-Menopausal**	
≤4 hours	0 (0%)	4 (8.2%)		3 (4.8%)	8 (7.3%)		9 (11.7%)	3 (2.8%)	
5-6 hours	17 (51.5%)	20 (40.8%)		20 (32.3%)	43 (39.1%)		31 (40.3%)	47 (43.1%)	
≥7 hours	16 (48.5%)	25 (51.0%)		39 (62.9%)	59 (53.6%)		37 (48.1%)	59 (54.1%)	
		p = 0.200 for sleep duration x menopausal status among those with TST < 1 year			p =0.479 for sleep duration x menopausal status among those with TST 1-4 years			p =0.050 for sleep duration x menopausal status among those with T.S.T. ≥5years	

Table 3. Associations between time since last treatment and sleep duration, stratified by cancer type, race, and menopausal status.

Treatment type did not modify the relationship between menopausal status and sleep duration or between time since treatment and sleep duration (data not shown). Time since treatment and sleep duration were examined with cancer type, race, and menopausal status (**Table 3**). Heterogeneity was suggested among survivors less than five years from their last treatment, with the observation of non-white survivors reporting fewer hours of sleep per night than white survivors (<1 year since treatment: p=0.003, 1-4 years since treatment: p=0.001).

Self-reported depression was analyzed with demographic characteristics, medical history, and health behavior characteristics (data not shown). Depression was not directly related to race, menopausal status, time since treatment, physical activity, or cancer type. Depression was inversely related to sleep duration (p = 0.022) and positively related to bodily pain (p < 0.001), physical pain (p < 0.001), and number of comorbidities (p < 0.001).

DISCUSSION

The findings in this cross-sectional study are consistent with those of Westin et al., who reported a more significant number of sleep disturbances among cervical cancer survivors.[28] We also observed non-white cancer survivors reporting fewer hours of sleep

per night than white cancer survivors. This observation is apparent across cancer type with potential modification by menopausal status, treatment type, and time since treatment. A previously published study with a similar focus on racial disparities in sleep used an actigraphy assessment and documented less sleep per night among non-white breast cancer survivors than white survivors.[33] Future studies that focus specifically on sleep duration and quality, with both subjective (e.g., self-report on Pittsburgh Sleep Quality Index) and objective (e.g., sleep actigraphy) assessments are needed more racially/ethnically diverse groups of cancer survivors.

Health behavior interventions to-date have focused on the increased risk of obesity-related cancer recurrence and the development of type 2 diabetes mellitus among cancer survivors. However, there is evidence that a more nuanced approach is needed to address health behaviors that would support sleep quality and mental health concerns. Several studies cite a myriad of biological, sociological, and environmental theories for racial disparities in sleep behaviors and sleep quality; however, there is limited research on specific cancer survivors' associations.[34,35] Interventions are needed to examine and address survivors' perceptions of their H.R.Q.O.L. and the risk of depression.[24,26,36,37] Negative coping styles and self-perceptions, coupled with sleep disturbances, may contribute to long-term and debilitating mental health conditions. As with the assessment of sleep, future studies should focus more narrowly on the dimensions of depression and distress in cancer survivors using instruments such as, but not limited to, the Beck Depression Inventory and National Comprehensive Cancer Network's Distress Thermometer.

In addition to expanding the lens of survivorship care beyond metabolic risk factors to include sleep duration and mental health, research and interventions also need to aggressively focus on accurately measuring and describing the H.R.Q.O.L. disparities in non-white populations and among those of lower socioeconomic status.[17,38,39] All cancer survivors have the potential to experience post-treatment effects. However, those survivors who live at the intersection of both racial and socioeconomic disparities in sleep duration and mental health will, arguably, have the largest barriers to knowledge and sustainable access to appropriate services.[40]

Despite the statistical significance of the results presented herein, it is crucial to consider this study's limitations. Questionnaires were sent through postal mail to the address listed in the cancer registry database. Email addresses were not collected by the cancer registry and were not available for this study. Lack of familiarity or personal connection with the institution making the request contributed to the low response rate. No financial incentive was offered for completion and return of the questionnaire, which may have impacted the response rate. Despite a response rate of 10%, which is lower than the target response rate for a single mailing, without incentives, of 15-20%[23,41,42] we did note that the respondents' demographics are comparable to the demographics of the population identified by the cancer registry. A cross-sectional sample of approximately 600 respondents does limit the magnitude of the impact of the stratified analyses. However, findings from this sample size can provide useful insight toward the specific aims of a future, subsequent study. This study's focus on gynecologic cancer survivors strengthens the literature, which has previously focused on breast cancer survivors. However, it is essential to consider the source population and the geographic and social confounders within Los Angeles County before extrapolating these observations to gynecologic cancer survivors at the state or national level. Given the lower representation of cervical and ovarian cancer cases and the lower representation of non-White cases in the L.A. County cancer registry, it would be prudent to over-sample these sub-groups in future studies.

CONCLUSION

This study highlights the importance of focusing in on depression and sleep duration in the context of cancer type, treatment type, exercise behaviors, and race to understand better health disparities among cancer survivors that might lead to long-term deficits in mental health and H.R.Q.O.L. Future studies should include an objective clinical assessment of disease burden using the Charlson Comorbidity Index for more recent cancer survivors, in comparison to those who have experienced more time since treatment cessation. This study suggests that disparities are most prevalent among cancer survivors that have more recently completed treatment. Additionally, non-white cancer survivors experience insufficient sleep duration and depression despite participating in physical activity, which has been previously shown to improve white cancer survivors' sleep and depression. Increased attention is needed for cancer survivors in the first year after treatment cessation to identify and mitigate racial and socioeconomic disparities in sleep duration and H.R.Q.O.L.

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AUTHORS' DISCLOSURES

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Ma'at Hembrick and Makala Conner graduated from Loyola Marymount University in May 2019 and each received a Bachelor of Science degree in Health and Human Sciences. Ma'at is working as an Office Manager at a dietitian's private practice named, Elizabeth Baron Cole & Associates. Makala works at Eco Works, a non-profit organization that informs Detroit Public School students about their environment and promotes sustainable living projects for students and faculty members.

PRESS SUMMARY

Among a surveyed group of gynecological survivors from the Cancer Registry, sleep quality was measured as a determinant of quality of health. Sleep quality among these survivors was also analyzed in relation to race, postmenopausal status, cancer type, and depression. In conclusion, this study found noteworthy relationships between the aforementioned variables and sleep quality, and further proposes exploring racial disparity in sleep quality among a larger, multi-ethnic group of gynecological survivors.

APPENDIX

Original Variable	**Data Analysis Format for Categorical**
Age	**Age Mean** 66.54 ± 2.6
Reported in years (continuous)	49-64 yrs old
	65-69 yrs old
	70 + yrs old
Ethnicity	**Ethnicity**
American Indian	Non-white
Asian/ Asian Pacific	Non-white
Black	Non-white
Hispanic	Non-white
Other	Non-white
White	White
Education level	**Education level**
<High School	≤High School
Some high school	≤High School
High school graduate	≤High School
Some college	Attended college
2-year college graduate	Graduated from either a 2 or 4 year program
4-year college graduate	Graduated from either a 2 or 4 year program
Menopausal status Are you currently in menopause?	**Menopausal status**
No	Premenopausal
Yes	Postmenopausal

Treatment Type	**Treatment Type**
Surgery	No chemo
Radiation	No chemo
Chemotherapy	Chemo
Blood Transfusion	No chemo
Other	Other
Time Since Treatment	**Time Since Treatment**
What was the date of your last treatment?	< 1year
(reported by month and year)	1-4 years
	≥ 5 years
Activity Level	**Activity Level**
Minutes spent exercising per day (continuous) multiplied by number of days spent exercising per week (continuous).	< 150 minutes
	≥ 150 minutes
Sleep Duration	**Sleep Duration**
4 hours	4 hours
5 hours	5 hours
≥ 7 hours	≥ 7 hours
Original Variable	**Data Analysis Format for Categorical**
Cancer Type	**Cancer Type**
What type of cancer were you diagnosed with?	Cervical
	Endometrial
	Ovarian
	Other
Fall recurrence How many times have you fallen within the past 12 months? (continuous)	**Fall recurrence**
0-1	Nonrecurrent
≥ 2	Recurrent
Fall risk Please respond to this statement: "I am at risk for falls."	**Fall risk**
Strongly Agree	Agree
Somewhat Agree	Agree
Neutral	Neutral
Somewhat Disagree	Disagree
Strongly Disagree	Disagree
Bodily Pain How much "bodily pain" have you generally had during the past 4 weeks, while doing normal daily activities?	**Bodily Pain**
Severe	Yes
Quite a Bit	Yes
Moderate	Yes

Very Little	No
None	No
Physical Pain Do you have a bone or joint problem in your leg that limits your physical activity?	**Physical Pain**
Yes	Yes
No	No
Depression In general, how much depression have you experienced in the past 4 weeks?	**Depression**
Severe	Yes
Quite a Bit	Yes
Moderate	Yes
Very Little	No
None	No
Comorbidities	**Comorbidities**
Has a doctor ever told you that you have/had: anemia, asthma, auto-immune disorder, bladder disease, breast cysts, chronic bronchitis, chronic fatigue, ulcer, chronic liver disease, emphysema, fibromyalgia, gall stones, hepatitis, hyperthyroidism, heart disease, kidney disease, osteoarthritis, osteogenesis imperfecta, osteopenia/osteoporosis, rectal polyps, rheumatoid arthritis, stroke, type I diabetes and type II diabetes Each condition counted to generate a categorical variable corresponding to the sum of conditions.	0
	1
	2
	3
	≥ 4

Table 4: Data collection and analysis format for demographic and health-related quality of life variables.

An Unlikely Symbiosis: Science and Law

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ABSTRACT
Science has historically held a position of high regard in society. Science is intimately connected to law. These disciplines meet in the courtroom. Due to the nature of civil and criminal disputes in the United States, litigators retain expert witnesses to explicate nuanced subjects, including science. Unfortunately, the common law system has not always favored sound science. This paper examines how science and law can work in concert to benefit all people. Some feel that scientists should simply educate courtrooms, but further scrutiny questions the feasibility of this approach. Understanding the sociology of scientific knowledge elucidates this debate and is applied to the forensic sciences. Science and law have the capacity to improve the human condition and increase equity among all people.

KEYWORDS
Science Communication; Expert Witnesses; Science; Public Perception; Law; Misinformation

INTRODUCTION

Scientific discovery assists in policy formation and societal advancement, as well as re-evaluating current claims regarding safety and well-being.[1] Societies encounter complex issues frequently, and the scientific method is an efficacious way to solve the problems people encounter. Due to the fact-finding nature of science, it carries a significant power to improve the human condition for the better.[1]

However, science does not exist in vacuum. Science is created and amended within the confines of human society, often intersecting with the law humans have created for themselves. Law and science cannot live independently. Science and law meet at an interesting crossroads: the courts. The individuals who litigate disputes in the courtroom may not understand the delicate, scientific nuances of every subject they litigate. Conversely, scientists may not be properly equipped to disseminate their findings in such a unique setting. This paper is written as a guide for maximizing the use of science in the courtroom to achieve equitable outcomes.

Part I: Literature Review

Scientific courtroom disputes are commonplace. A simple search of personal injury dockets in 2019 reveals that attorneys filed more than 300,000 claims in the United States and its territories. Not all of these cases will go to trial, nor will all require scientific experts, but some cases will require expert testimony in open court. For instance, cases regarding defective ear plugs and vaping will require scientific knowledge to guide judges and juries in their decision-making process. The wide variety of cases supersedes the readily available knowledge of courtroom fact finders. For this reason, expert witnesses are allowed in the courtroom, and allowed to be compensated for their testimony, a practice that is typically forbidden in regular courtroom operations.[2,3] Expert witnesses have the potential to assist judges and juries in reaching sound conclusions.

The United States relies on the common law system to resolve formal disagreements. This system of dispute resolution rests on the principle of *stare decisis*, a Latin phrase known commonly as "let the decision stand." This means that when judges craft opinions, they look to the previously written body of law on the subject, whether it involves compensation in asbestos cases, or medical malpractice, to name two examples. This creates a body of rule that guides future judges and attorneys. Precedent forms predictions of success at trial. Attorneys can inform clients of the best route to recoup damages or seek relief from adverse legal claims.

Misinformed science can become enshrined in precedent. Judges have previously relied on dubious evidence to convict innocent people.[4] Any scientist who enters the courtroom must approach their testimony with the understanding that flawed science may have prevailed in the past, and correcting that science requires careful explanation. The courts may not defer to new advances in science immediately. The phenomenon of judicial reticence to acquiesce to current science is illustrated by the citation of one faulty statistic regarding sex offender recidivism in a United States Supreme Court opinion. Supreme Court Justice Anthony

Kennedy cited a statistic that an estimated 80% of untreated sex-offenders re-offend. This statistic was then parroted throughout lower courts, negatively affecting sentencing outcomes for convicted individuals.[5] When this statistic was tracked back to its origin, no acceptable academic proof was provided to support it.

Scientific inquiry is a process that is not intuitive to those not involved with it on a daily basis.[6, 7] Science uses an argumentative, skeptical approach to discover information. Scientists who want to publish and disseminate their work present the data in the peer review process, where their peers scrutinize and question the results to ensure they are accurate. This process of peer review is healthy and typically creates constructive dialog. However, peer review can lead to disagreements as to the exact nature of stated conclusions, and these disagreements, while mostly benign, can become ammunition for legal disputes.[8, 9]
One of the most well documented cases of using innocuous debate in the scientific community as the basis for rejecting a scientific consensus was the fight against tobacco in both the court of public opinion and court of law. Science does not provide guarantees, and when it comes to toxins like those found in cigarettes, it measures the toxin exhaustively and sets levels of allowable intake. This intake level is not a sufficient condition to guarantee the absence of adverse health outcomes, but rather a buffer that ensures the levels that cause acute or chronic toxicity are generally not present.[6] A lack of full guarantee was harnessed by the tobacco industry to sow doubt about the extent of health risks regarding its products.[8] Testifying before the United States Congress during the "high-tide of anti-smoking sentiment," tobacco executives stated that cigarettes may have adverse effects, but the facts are not conclusive.[9, 10] The scientific community saw the qualified conclusion more as a "benign contestation" rather than a deep foundational dispute regarding the malignance of tobacco.[7]

Attorneys play in these gray areas created by scientists, questioning expert witnesses' dedication to their conclusions. To defend science, the scientist must be ready to explain the difference between deep divides in the scientific community and mere quibbles over minor aspects of the issue at hand.[8] As expert witnesses become more commonplace in the courts, the issue of expert witnesses themselves has been brought before the United States Supreme Court on multiple occasions. For nearly 70 years, *Frye v. United States* was the prevailing law.[11] Under *Frye,* scientific testimony simply had to be generally accepted. A community of so-called scientists could coalesce and pass off questionable science as "generally accepted." Realizing some flaws in this standard, the court strengthened it in *Daubert v. Merrell Dow Pharmaceuticals* in 1994.[12] This ruling created a focus on the reliability of results obtained. The courts now ask how the results were obtained, and whether said results are reliable and replicable according to the particular field. *Daubert* also ushered in Daubert Challenges, in which one side can challenge an expert witness and how they arrived at their conclusions. The Supreme Court gave examples of admissibility criteria, such as peer review, general acceptance of procedures utilized, rate of error, and replication of results. This also established the judge as the gatekeeper of admissible expert testimony in trial courts. As it so often does, the Supreme Court clarified the gate-keeping role of judges, as well as appropriate appellate review standards of expert testimony in *General Electric Co. v. Joiner.*[13] Under *Daubert* as clarified by *Joiner,* judges are allowed to examine conclusions proffered by experts, in addition to experts' analysis of methods. These cases serve as guideposts to scientists and attorneys preparing to introduce scientific testimony in court. The testimony must call upon generally accepted scientific procedures, reliably attained through discipline-specific procedures. Furthermore, the scientific community must support the means used to derive conclusions utilized in expert testimony. These results must then be framed in an understandable manner for the judge, who has the final say regarding the ultimate admissibility of any proffered testimony. These rules were eventually consolidated into Federal Rule 702, which explicitly states what the courts said about expert testimony. The expert must be qualified to offer opinion, the opinion must be relevant to the issue in dispute, the methods used to find facts are reliable, and those methods were applied correctly to the derivation of fact. This rule has rendered the criteria in *Daubert* generally moot, but courts have still retained their discretion in what evidence is allowed in trial.[14, 15]

Clearly, judges play a substantial role in the quality of evidence used in trial. This role is a weighty burden because their decisions may be used in future cases. Therefore, the gatekeeper role is absolutely essential in preventing inaccurate information from entering the courtroom and remaining there to harm innocent people in future cases. Trial attorneys are key allies to the propagation of good science in the courtroom, as they are responsible for the caliber of evidence introduced at trial.
The summation of the history of expert testimony in the courtroom is intended to help scientists understand legal challenges their work might face, so that they can be prepared to defend it when called upon. In describing the function of expert witnesses, the easiest path forward may seem to be for attorneys to simply fill in the gaps of understanding for judges and juries in technical debates. The notion that science will be accepted by lay people upon explanation is referred to as the deficit model of thinking. The deficit model of thinking has been roundly rejected by those who study the science of communication.[7] Simply telling a judge or jury that certain facts exist and are pertinent is not sufficient to produce a favorable outcome for reliable science. All those who make up the cast of a court room trial bring pre-existing notions of science with them. Not all notions are favorable to science. In fact, several modern challenges afflict lay understanding of science. Due to the chaotic manner in which the scientific process proceeds, finding an absolute truth that all jurisprudential actors agree on may not be possible.[9] Justification for this difficulty is now provided.

An overarching issue of scientific perception is the plague of misinformation ravaging online communities. This problem could be a consequence stemming from the loss of the Fairness Doctrine.[16] In the early days of radio, commentators were required to provide equal airtime to various ideologies. Requiring a left-leaning talk show to give time to their counterparts on the right, and vice versa may seem ludicrous. However, the Fairness Doctrine was temporarily upheld in the United States Supreme Court in a unanimous 1969 decision on grounds that the amount of "speech" on the radio was capped. The court reasoned that if one perspective dominated the finite radio waves, the American people would be deprived of a popular viewpoint, or alternate viewpoints in general.[17] With the advent of the internet, the limits constraining the amount of available speech melted away, and in 2011 the Fairness Doctrine was officially repealed.[18] Now that political commentators and news broadcasters have no need to consider opposing viewpoints, partisan strongholds have since quickly developed.

The internet was one of the driving factors behind increasing the amount of available "speech." The internet does not face the same restrictions as the radio and contains billions of pages. Additionally, the average user's access to these pages is ever changing based on the search engines they are using.[19] The available viewpoints are legion, and this disharmonious choir of opinions can be quite disorienting, contrary to the belief that more information is better.[1]

A microcosm of the online landscape is Facebook. Nearly half of the world trusts Facebook as a source for news.[20] This dependence makes the social media platform ripe for abuse and helps accelerate the breakdown of credible information sharing. The massive Cambridge Analytica Scandal that rocked millions of Facebook users exposed this vulnerability.[21] The big-data company Cambridge Analytica sold the political preferences of Facebook users to political machines, who used the data to target users based on their political beliefs. The confirmation bias was leveraged to feed users information that matched their beliefs.[16, 22] The confirmation bias is the need to accept narratives that match personal ideologies, and is a built-in part of human neurobiology.[23] This bias helps actors to rationalize their behaviors against facts or information that may not match their beliefs.[24] Social media catered to the predictable human psychology of constructing of echo chambers made up of people who agree with each other. These biases were exploited by algorithms that pushed consumers of social media toward information that fit their existing beliefs, with no guarantee of the veracity of that information.

This path to misinformation created unfortunate consequences for scientists striving to educate the public on their work. Science is a never-ending process and sometimes examines issues that the public may wish to not have examined.[1] When partisans are confronted with scientific information that does not align with their beliefs, the initial belief is thought to be strengthened even in the face of contradicting information.[22] This phenomenon has become painfully apparent with the advent of the novel coronavirus, (Sars-CoV-2, or COVID-19). Contemporary Facebook newsfeeds are filled with politicized memes advocating for and against the wearing of facemasks. The Center of Disease Control issued initial guidance that facemasks be worn only by those with a confirmed diagnosis of COVID-19.[25] As the scope of the disease grew, the CDC released new guidance that all people should wear facemasks in public.[25, 26] Editorials and social media posts criticizing these actions are legion, another example depicting the complex relationship of science with the public.

These findings have caused some in the scientific community to question whether effective scientific communication is possible in a society mired in scientifically inaccurate information.[15] Misinformation became so infamous that the World Economic Forum declared misinformation a crisis on par with terrorism.[20] Misinformation, and the vastness of available data complicate the dissemination of scientific knowledge, and threaten to block a working understanding of science that will empower judicial fact finders.[1, 16, 20, 22]

Another issue that contributes to the misinformation crisis is the overrepresentation of scientific fraud. The vast majority of scientists conduct their research in good faith, working to find solutions to problems. Society is better because of their efforts. However, a small number of unscrupulous actors pursue scientific knowledge without these benign intents.[27, 28] Scientists have been accused of providing evidence that ostensibly clears products or advances in medicine for mass distribution but are ultimately false positives. One example is cancer research. Society has long sought a silver bullet to use against this dreaded disease. Some scientists were eager to oblige society's yearnings, and spuriously claimed they had found this silver bullet. When these fraudulent claims were exposed, scientists retreated disgraced from their claims and the 24-hour news cycle used their lack of scruples as evidence that science as a whole is failing.[16, 27] News agencies correctly function as watchdog entities, and the reader need not suppose that these channels abuse their power by shining the detecting light of public scrutiny on those who behave with impropriety. The issue lies with the availability heuristic of those who consume news. The availability heuristic is a psychological phenomenon that explains certain aspects of decision making. When people form opinions of local crime, or prevalence of small airplane crashes, the amount of information available to the person predicts their mental representation of the frequency and severity of these events.[29] These representations are typically biased and inaccurate. When consumers frequently see stories of scientific impropriety, these biases become active and consumers begin to believe that impropriety is the norm in the scientific process.[16]

Germane to fraud is the alleged replication crisis plaguing many different scientific disciplines. Critics allege science is at a standstill due to the rise in failed replication of original, promising research. Indeed, retractions of initially published research are rising.[27] This evidence led to claims of science being broken, which seriously threatens the legitimacy of findings and science generally. The public began to wonder whether any scientific advances can be trusted, or if scientists in white lab coats will retract research when another scientist attempts to replicate their findings and fails. This concern, similar to the fraud concerns, is not being contextualized appropriately. In a study of scientific articles published from January 2000 to December 2015 by the peer-reviewed journal BioMed Central, the authors found that 134 studies had been retracted.[30] From an outsider's perspective, 134 studies seems to be an alarming amount of research that had initially passed the muster of peer reviewers, to ultimately be pulled from publication. Upon further inspection, this number makes up 0.07% of all published articles from BioMed Central. Invisible to the public are the volumes of studies that proceed with propriety. Additionally, nearly half of these retractions came from the authors themselves.[30] Science is a self-policing industry, and internal criticism affecting change in the scientific community demonstrates the scientific process is alive and healthy. Thus, the issue is not fraud or challenges arising from replication questions, but the public perception of these challenges.

Despite the positive prognosis of science resulting from correct framing of the fraud and replication issues, the problem is being presented to the media as an indication that science is dying. The alleged crisis of confidence is exacerbated by some in the communication industry who use alarmist language when describing concerns surrounding replication. For instance, science reporter Richard Harris wrote in the New York Times about all the ills of science in an article entitled "Rigor Mortis: How Sloppy Science Creates Worthless Cures, Crushes Hope, and Wastes Billions." In the world of superficial scholarship, this headline is a spark that ignites a bonfire of backlash. However, when asked further about this "Rigor Mortis," Harris confesses that acknowledging that some studies are flawed is actually a positive step in the right direction.[31]
The challenges of misinformation, fraud, and replication threaten the ability to advance science, as well as its legitimacy in the court room. For scientists who do venture into the courtroom, the threat exists of some unfortunate consequences, such as loss of credibility or stigmatization.[32] These consequences may occur even if the scientist or expert is participating in good faith. Despite these risks, venturing into the courtroom is a pressing need for the long-term viability of science. As noted throughout this paper, science provides real value to society, and scientists themselves are best prepared to share and defend its results.[6, 33] However, defending science cannot be left to scientists themselves. Attorneys and judges must take an active role in endorsing sound science because simply informing juries is not adequate.[7]

Part II: Sharing Knowledge in the Courtroom
Finding common foundational truth is a difficult endeavor. Some believe that science is created with firm rules and produces absolute truths that should guide society's every step. Conversely, others see scientific participation as open to all, and the results open to more liberal intrepretation.[34] These differences in the perception of science led scholars to explore the underpinnings of knowledge, and how societies manufacture knowledge.[9, 33] This is the sociology of scientific knowledge (SSK). Jasanoff has made invaluable contributions to this field, some of which are cited in this paper.[9, 34] The literature on how knowledge is derived constitutes a valuable part of the science and law discussion. Each piece of scientific knowledge, or fact, exists inside societal contexts. The courts play a valuable role in deconstructing scientific processes to better understand how they fit inside these contexts.[9, 34]

Social institutions largely govern the formation of these contexts.[34] These contexts are not consciously noticed until they are deconstructed. Deconstruction takes place when scientists begin to examine why they research the subjects they research. Scientists often state their conclusions only follow from observable facts, but these facts and conclusions are usually products of the contexts they originate from. For example, agricultural scientists investigating the production of different crop varieties conclude that some varieties yield better than others. The observation is ostensibly "true," but crop scientists are asking these questions because the institutions around food production prioritize increased yields. These institutions are made of consumers clamoring for better food at lower prices, and corporations striving to meet those needs. Therefore, the "fact" that one variety yields better than another originates from the goal to satisfy market demands. One could also observe that some crop varieties have different colors or sizes, but they are typically not relevant and therefore not included as facts despite other observations of qualities that are also "true."

As science has become more sophisticated, institutions have looked to add science to criminal law, promising greater accuracy in delivering justice. Societies generally desire to punish lawbreakers, especially in the case of violent crimes. The masses desire to feel safe, and there may be pressure to find facts that incarcerate alleged lawbreakers. Several disciplines lacking rigor, and while well-meaning, have used these incentives to enter the courtroom and gain significance and even prestige. Among these dubious practices is bite mark analysis.

Bite mark analysis deserves extensive review because the damage it has done to the basic tenets of a fair criminal justice system. The Sentencing Project is a non-profit institution that examines issues surrounding incarceration in the United States. In a 2018 report to the United Nations, this organization examined incarceration in the United States and found that people of color interact with police more often, are incarcerated at higher rates, and serve longer.[35] These outcomes are due in part to the inclusion of science that in many cases does not meet the appropriate standards of review established by the US Supreme Court. Removing bad science from the court room may increase equity in sentencing. Relying materially on poorly constructed science to place someone in prison should not occur in a society that claims due process rights for all, as promised in the fourteenth amendment to the US Constitution.[36]

Howard v. State illustrates all aspects of this issue perfectly. Eddie Lee Howard was convicted using bitemark evidence from the infamous "forensic odontologist," or bite mark expert Dr. Michael West, who achieved prominence from his bite mark testimonies in several high-profile cases involving violent crime.[39] Howard was originally convicted for a crime that occurred in 1992, the murder and apparent rape of an 84-year-old woman in her own home. The crime was heinous; justice needed to be served. Dr. West provided the only incriminating evidence against Howard: bite mark analysis on the bite marks left by the perpetrator on the victim.[38] Howard struggled to appeal his case through the system, claiming that bad science of forensic odontology had been used to convict him. After years of procedural slog, his appeals were denied in 2006. As written earlier, the judges who handed this decision down relied on previous judicial opinions to support their decision, including *Brooks v. State*.[39] The *Brooks* case also relied on bite mark evidence to convict the alleged perpetrator, Levon Brooks. Brooks would be exonerated in 2007 by DNA evidence.[38] The appellate court also used *Daubert* to insist that the responsibility of admitting evidence lay solely at the door of trial courts. Instead of helping rid the court of bad science, *Daubert* allowed the bite mark evidence to continue. After winding through decades of legal procedure, Howard remains on death row with his case before the Mississippi Supreme Court.[40]

As more scientists turned the eye of scrutiny on dental odontology, several issues were raised with the practice. No acceptable error rate existed, meaning bite marks of two different people could be confused. The scientific community, as described previously in this paper, did its job and ousted Dr. West from its ranks.[41] Sadly, the damage done to Levon Brooks and Eddie Lee Howard cannot be reversed. The deconstruction included in the SSK could have prevented such controversial evidence from finding its way into American courts. The cynical critic might counter that bite mark analysis is the exact reason why science should be devalued or even excluded from courts. However, abandoning science would be foolhardy. Science can still provide answers and has an efficacious process of peer review to guard against fraud and misinformation.
Howard is a cautionary tale. Courtrooms are detailed places that require exactness, and the attorney is a key ally in preparation. The most effective scientists enter the scrum of the courtroom only after adequate preparation from attorneys.[42] They can advise scientists how to effectively frame and contextualize their knowledge so that juries and judges will fully benefit from the testimony. The American Bar Association has many resources on proper preparation and should be consulted for best results. This point cannot be overstated because of the disproportionate value lay juries, and sometimes judges, place on scientific evidence.[4] Because the mood of the audience is paramount to how a message is understood, proper presentation is vital to the success of expert testimony.[43] The best expert testimony uses the role of a teacher for the expert witness, that meets judges and juries where they are and helps them understand complex issues in a simple way.[6, 7, 41, 44] Teaching can help, but recalling the deficit model of thinking, scientists cannot stop at education. Deconstruction of issues can help unravel the biases lay fact finders bring with them into the courts. When deposing an expert witness, an attorney might walk the scientist through the basis for why they do their research, and why it is important to their discipline.

Conclusion

Science plays an invaluable role in society but is consigned to a relationship with man-made laws and systems. Science faces many challenges that threaten to impede its forward progress, such as fraud and replication concerns. The SSK and the deficit model of thinking inform scientists that the better way to share science is by deconstructing scientific phenomena and providing context. The courtroom is the crucial space for advocating on behalf of sound science.

Society stands in need of scientific communication. Achieving this goal requires scientists and legal professionals to work in concert with each other. In an increasingly partisan environment, speaking in terms of scientific fact has never been more important.[16] Scientists' time and resources are continually limited, but communication should be an essential component of their effort due to the far-reaching impact of that communication. Furthermore, the plague of misinformation threatens to engulf society. If the public cannot see correct and reliable science germane to their lives, scientific progress may never achieve its lofty goals of bettering society, and science itself may lose its legitimacy.[6, 33, 44] This would be a tragedy because scientific research can offer much in terms of healthcare, food production, and infrastructure. From the perspective of attorneys, their knowledge is vast regarding the nuances of legal procedure, but they can benefit from hearing the informed opinions of scientific professionals. This specialized knowledge can aid lawyers as they formulate their arguments and case strategy. Respectable, honest scientists are

irreplaceable, and their communication has never been in greater demand than in these times of misinformation. However, these scientists can only succeed in their efforts with the help of legal professionals who are competent in correctly framing robust scientific results.

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PRESS SUMMARY

Science and law need each other, but problems occur when science is used in law. The common law focus in American court systems can be problematic. These problems have not always produced the best outcomes for those on trial. By harnessing the sociology of scientific knowledge, these shortcomings can be addressed, and science and law can work together in achieving equitable justice and pushing society forward instead of pulling it backwards.

Microfibers in *Mytilus* species (Mollusca, Bivalvia) from Southern California Harbors, Beaches, and Supermarkets

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ABSTRACT
Plastic microfibers are an emerging threat to terrestrial and aquatic habitats worldwide. They are equivalent in size to planktonic organisms, making them available to a range of invertebrates. Bivalve mollusks can ingest and accumulate plastics via digestion and adherence to soft tissue. We determined the frequency and characteristics of microfiber pollution from wild *Mytilus californianus* and farmed *Mytilus edulis* populations that were collected from southern California harbors, beaches, and supermarkets (n=4 per site). Mussel organic matter was dissected using 30% H_2O_2. After adding a saline solution to separate the fibers, the liquid was filtered by vacuum filtration. The remaining fibers were examined with a magnification of 1~8x. In this short-term survey, the abundance of microfibers by sample and by shell length showed a significant difference between the harbor and beach sites. However, there was not a significant difference between the wild and farmed mussels examined. This study revealed widespread microfiber pollution and uptake by mussels in these locations and reinforces how bivalves can be used as a bioindicator of microfiber pollution.

KEYWORDS
Microplastic; Microfiber; Mytilus; Biomonitoring; Bivalvia; Seafood; Human Health

INTRODUCTION

The large-scale production and use of plastic only dates back to 1950. As of 2015, approximately 6,300 million metric tons (Mt) of plastic waste has been produced with 79% accumulating in landfills or the natural environment.[1] This rapid growth in plastic production has led to an abundance of discarded plastics worldwide. Because plastics are manufactured to be durable and non-biodegradable, they are persistent in the natural environment and thus can negatively influence organisms at both the macro- and micro-level.[2] For example, ingestion of large inorganic plastics, defined as macroplastics (> 5 mm), can block an animal's digestive tract, leading to starvation or digestive tract obstruction.[3]

Although the effects of macroplastics are well documented,[3] microplastics are of growing concern in the marine environment due to their high abundances in the water column, ocean sediments, and marine organisms. Microplastics, typically defined as less than 5 mm in diameter, are caused by the degradation of macroplastics, by wave action, photodegradation, or other environmental factors.[3] Microplastics are equivalent in size to planktonic organisms and other food particles that organisms ingest, making them available to a range of marine organisms. Their size allows microplastics to move readily through marine trophic systems.[4] Numerous laboratory trials have investigated the ingestion and accumulation of microplastics within marine organisms.[2, 5, 6] Although no significant detrimental effects have been observed, the abundance of microplastics in the environment raises toxicity concerns.[5] Their large surface area-to-volume ratio causes microplastics to concentrate high levels of persistent organic pollutants (POPs). Whether these high levels are physiologically meaningful is a point of concern and a need for research. In addition, organic pollutants may have the potential to act as a chemical inhibitor within living organisms that may bioaccumulate within food webs.[3]

Microfibers, a subcategory of microplastics, are a pollutant caused by the degradation of synthetic fibers.[7] During the machine washing of polyester, polypropylene, acrylic, nylon, or other synthetic garments, large numbers of microfibers are discharged into wastewater with each garment releasing up to 10^7 fibers per wash.[8] The fibers enter the environment directly through septic systems and reused water, or indirectly through wastewater treatment plants.[9, 10] As a consequence, synthetic fibers are the most abundant type of microplastic in the marine environment.[8]

We studied the uptake and retention of microfibers by examining two species of the cosmopolitan marine mussel genus *Mytilus*: (*M. californianus* and *M. edulis*). These species are widespread and a vital food source for a range of organisms, including humans.

Mollusks have been used as bioindicators of marine pollution in multiple studies.[11, 12, 13] Mussels are sedentary suspension feeders that ingest nutrients by straining particulate matter from the water column. They filter water over their gills where they capture planktonic organic material and pass it to their mouths. Mollusks have minimal ability to excrete pollutants through their organs and tissues, causing them to have a greater ability to bioaccumulate contaminants than other organisms.[14] Their high sensitivity to pollutants enables their use as an environmental early warning system. Thus, the large number of microfibers entering the Pacific coastal area daily subject the mussels to accumulation and retention of the plastics through ingestion, digestion, and adherence.[4]

We conducted a three-month-long survey on microfiber accumulation in wild and commercial *Mytilus* spp. collected from three types of sampling sites: harbors, beaches and supermarkets. The mussels were collected from four docks located in marine harbors, four rock jetties located at coastal beaches, and four supermarkets located in southern California. The sites were chosen based on their proximity to large sectors of commercial and residential activity. We determined the difference in abundance and characteristics of microfiber pollution in wild *M. californianus* communities and farmed *M. edulis* samples between the three site types. Although *Mytilus* usually occurs in shallow marine environments, the collection sites differed in terms of substrate, tidal current, and wave action. In addition, the prevalence of wastewater, runoff, and water reuse in residential areas varied between locations. Due to limited wave action and a higher prevalence of wastewater near harbors, we expected the mussels collected in these locations to exhibit an increased intake of microfibers when compared to samples collected near coastal beaches. In literature, reports have found that farmed mussels have significantly higher microplastic concentrations than wild-caught mussels. This is due to farmed mussels often being cultured in coastal areas and grown on polypropylene plastic lines.[14] Due to these factors, we expected the farmed mussels to have an increased intake of microfibers when compared to the wild samples.

METHODS AND PROCEDURES

Sample collection

Mussels were collected randomly from four harbors, four beaches, and four supermarkets throughout southern California (**Figure 1**). *A Review of California Mussel (Mytilus californianus*), *Fisheries Biology and Fisheries Program* was used as a reference for species identification.[15] *M. californianus* was distinguished from other organisms by its coarse thick shell with radial ribs, bluish-colored outer layer, bright orange meat, blunt shell shape, and size 130~150 mm. The harbor mussels were collected from Ventura, Newport Beach, Santa Barbara, and Morro Bay. The beach mussels were collected from Ventura, Mission Beach, Oceanside, and Avila Beach. *M. edulis* was collected from supermarkets due to its intensive commercial and aquaculture use. The *Marine Species Identification Portal* was reference.[16] The mussel was distinguished by its solid, triangular shell shape, dark purplish-blue outer layer, and size 50~100 mm. The mussels were farm-raised, originating in Washington and California. These organisms were collected from Whole Foods, Gelson's Market, Vons, and Costco located in Ventura County. Eighteen mussels were collected from each of the twelve sites and transferred to the laboratory. The organisms were then transferred to a filtered, natural seawater tank to allow them to clear their gut for dissection. The mussels ranged in weight from 0.69 to 21.3 g ww (wet weight) and in length from 1.60 to 12.8 cm.

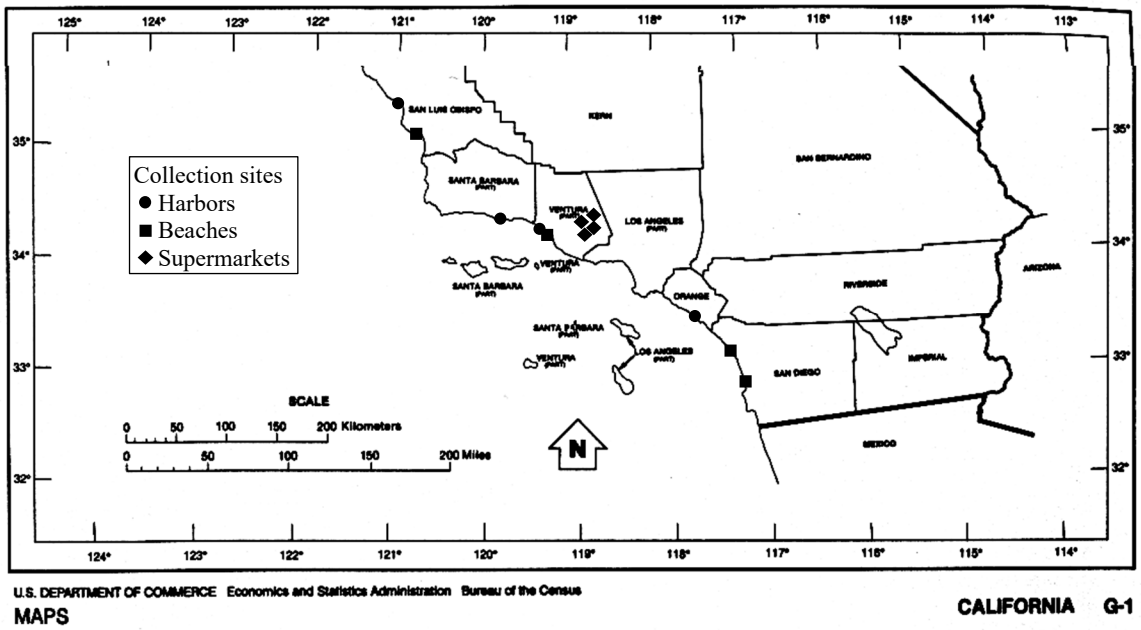

Figure 1. Sampling sites of mussels along the southern California beaches and harbors. Supermarkets were selected due to their proximity to California Lutheran University.

Minimizing contaminants
Given the abundance of microfibers in the environment, procedures were followed to minimize contamination during transport or in the lab. To minimize contaminants, all experimental processes described below were completed as quickly as possible. During mussel dissection, only natural fiber clothing and standard non-plastic equipment were used, such as steel dissecting tools and glass petri dishes. Equipment and processed filter paper samples were placed in sealed containers and stored in a fume hood. Methodological controls, such as blanks, were not used due to limited resources, time, and funding. Although the complete removal of fibers from an environment is impossible, these procedures have shown to minimize contaminants.[3]

Sample preparation
The weight of the organic matter and shell length of each mussel was recorded using a Vernier caliper and precision balance, respectively. To dissect the mussels, the valves were cut open by inserting a metal scalpel between the two valves on the dorsal side and the anterior adductor muscle. The organic matter of each mussel was then weighed and recorded. The organic matter of two mussels were combined and placed into 500 mL individual glass bottles. The combined matter was regarded as a sample. Thus, nine samples with a total of 18 mussels were prepared at each site. These replicates were used to measure variation in the experiment and locate outlier results. Four of the mussels were contaminated during the sample preparation process. Therefore, one sample from Newport Harbor and Oceanside Beach were rejected.

Depending on the weight of the organic matter in each bottle, 30 to 70 mL 30% H_2O_2 was added to digest the organic matter.[4] For 24 hours, the beakers were covered with aluminum foil and placed in a water bath incubator at 65 °C.[17]

After digestion, 100 mL of NaCl solution was added to each beaker to separate the microfibers from the dissolved liquid of the organic matter via flotation.[6] The mixture was left for 24 hours in the water bath incubator. The liquid was filtered by vacuum filtration over a 5 μm cellulose nitrate membrane filter.[6] The filter was placed in a sealed container for further observation under a microscope.

Observation and validation of microfibers
All microfibers on the filter (n=106) were examined, counted, and characterized under a Nikon Stereo Microscope SMZ800N and examined with a magnification of 1~8x. Images were taken using an iPhone camera. We recorded organic matter weight (g), shell length (cm), and fiber color for each sample. No other type of microplastic was analyzed. A visual assessment was used to identify and count the number of microfibers. Approximately 60 minutes were spent examining each filter. Each microfiber was identified by observing the characteristics described in Hidalgo-Ruz *et al.,* 2012.[18]

Data analysis.
Statistical analyses were conducted using Excel. A one-way analysis of variance (ANOVA) was used to compare microfiber concentrations from mussels collected at the harbor, beach, and supermarket sites. The average abundance of microfibers per sample, per weight, and per shell length were compared in this analysis. If these tests indicated significant differences, then a Tukey test was used to determine the significant location. In addition, two simple linear regression analyses were used to determine whether weight or shell length is a better predictor of ingested microplastics. Statistical differences were considered significant when $p < 0.05$.

RESULTS
In this study we found a total of 1,038 microfibers in 212 mussels with 99.98% of the mussels containing microfibers. The most abundant color of microfiber identified was black at 43%, followed by blue at 30%, transparent at 17%, and red at 10%. An example of a blue microfiber is shown in **Figure 2a**. A pilot study conducted by the author revealed that microfibers occurred on the gill surfaces, stomach area, and intestines of the mussels. An example of a microfiber on a gill is shown in **Figure 2b**.

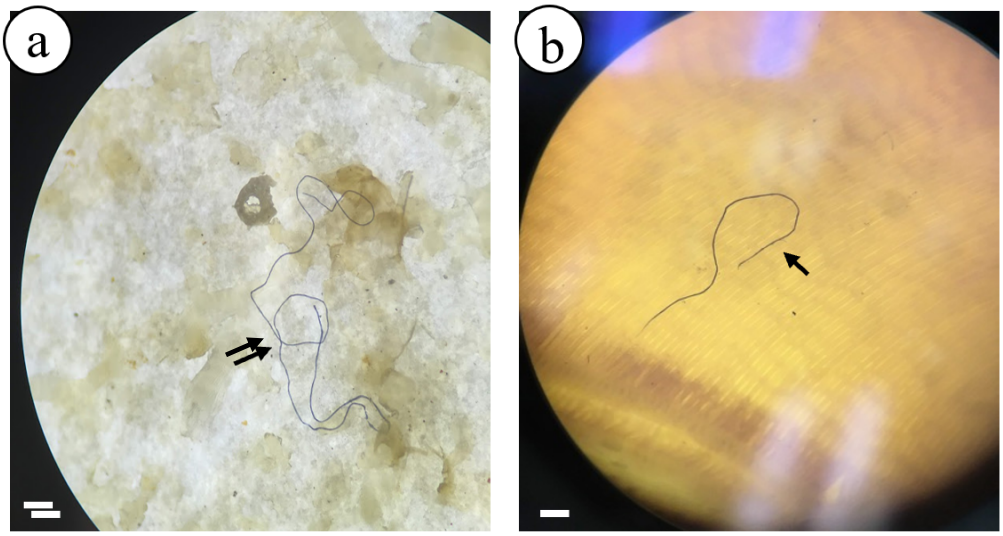

Figure 2. Close-up images of microfiber on filter **(a)** and on dissected gill of mussel **(b)**. Scale bar = 1 mm.

Microfiber abundance was significantly higher at the harbor sites than at the coastal sites. A one-way analysis of variance showed that the harbor sites were significantly higher in regard to fibers per sample ($p = 0.006$) and per shell length($p = 0.049$). There was not a significant difference between fibers per weight ($p = 0.253$). A Tukey test indicated that Newport Harbor was significantly higher than the other harbor sites when comparing fibers per sample ($p = 5.07 \times 10^{-7}$), per weight ($p = 5.30 \times 10^{-7}$), and per shell length ($p = 6.69 \times 10^{-8}$). There was not a significant difference between the wild and farmed samples collected. However, a Tukey test indicated there were significantly more fibers per gram at Gelson's Market than Whole Foods ($p = 2.00 \times 10^{-3}$). Two simple linear regression analyses revealed that there was no correlation between the number of microfibers and weight ($p = 0.235$) and between the number of microfibers and shell length ($p = 0.343$).

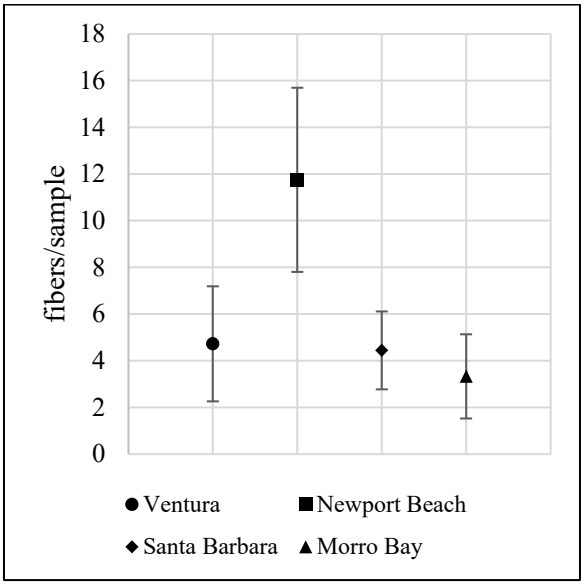

Figure 3a. *Mussels collected from harbors.*

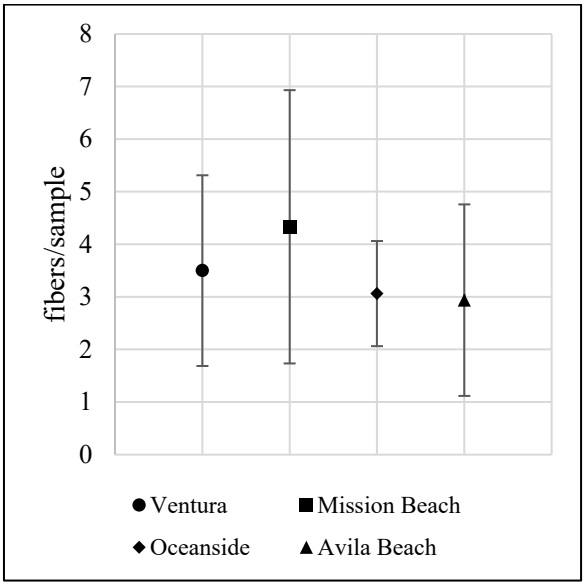

Figure 3b. *Mussels collected from beaches.*

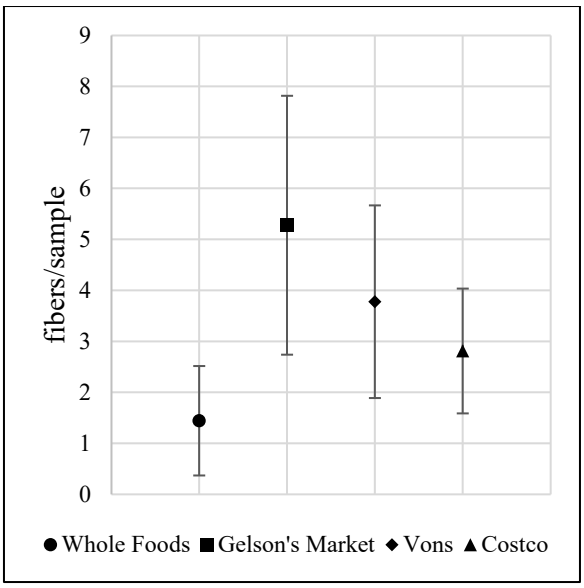

Figure 3c. *Mussels collected from supermarkets.*

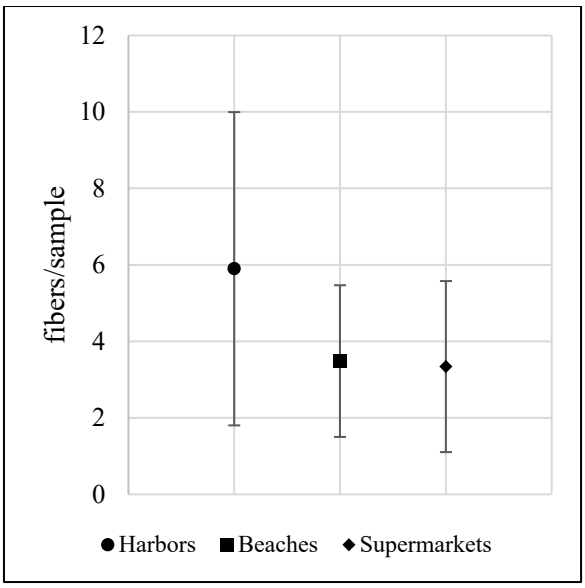

Figure 3d. *Mussels collected from the three site types.*

Figure 3. Comparison of the average number of microfibers in wild mussels collected from harbors and beaches, and farmed mussels collected from local supermarkets. Bars represent mean value +/- Standard deviation. Outliers have been removed.

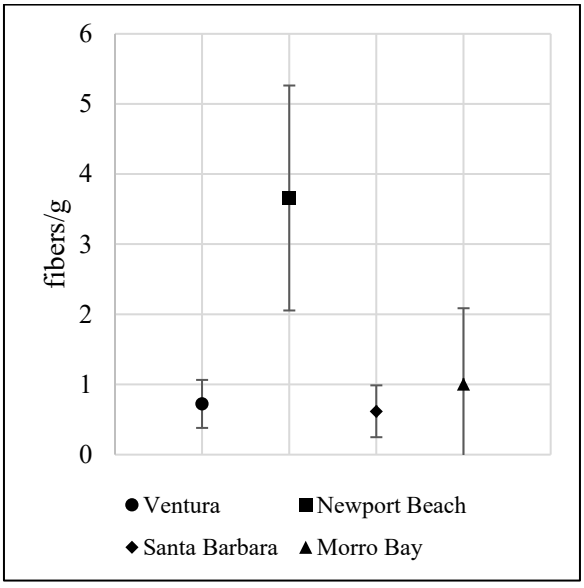

Figure 4a. *Mussels collected from harbors.*

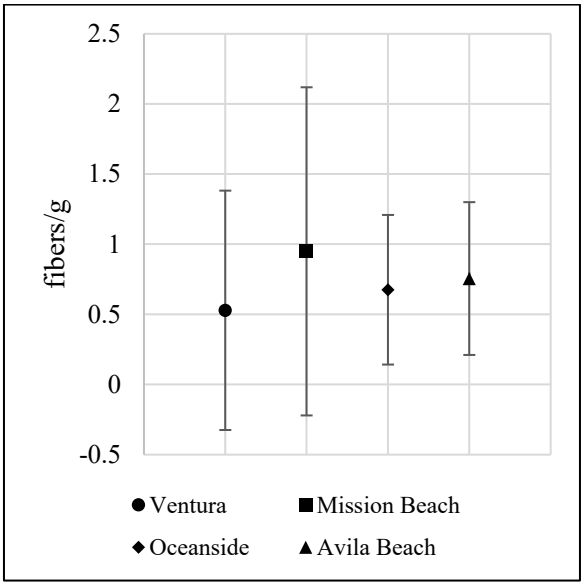

Figure 4b. *Mussels collected from beaches.*

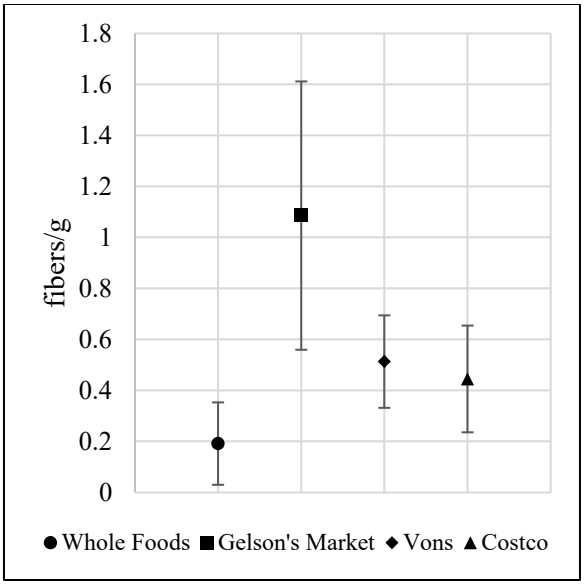

Figure 4c. *Mussels collected from supermarkets.*

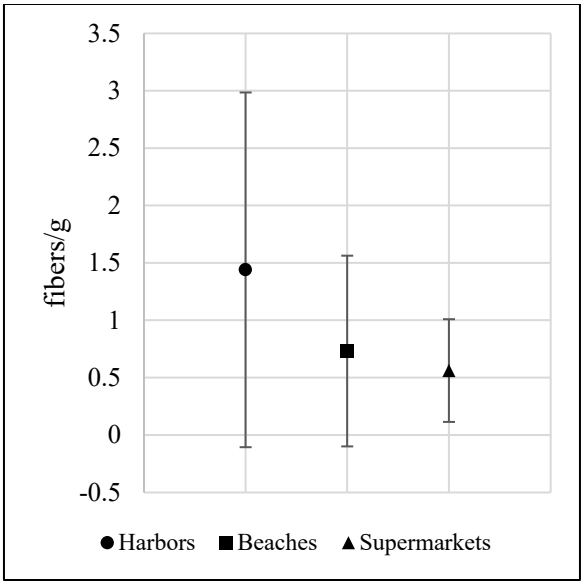

Figure 4d. *Mussels collected from the three site types.*

Figure 4. Comparison of the average number of microfibers per weight in wild mussels collected from harbors and beaches, and farmed mussels collected from local supermarkets. Bars represent mean value +/- Standard deviation. Outliers have been removed.

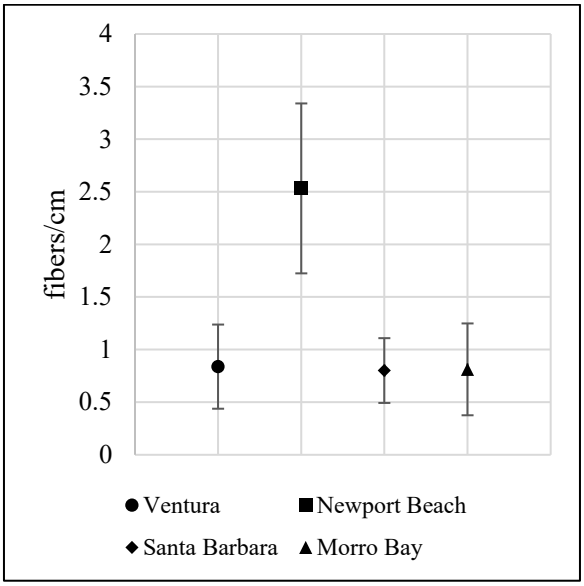

Figure 5a. *Mussels collected from harbors.*

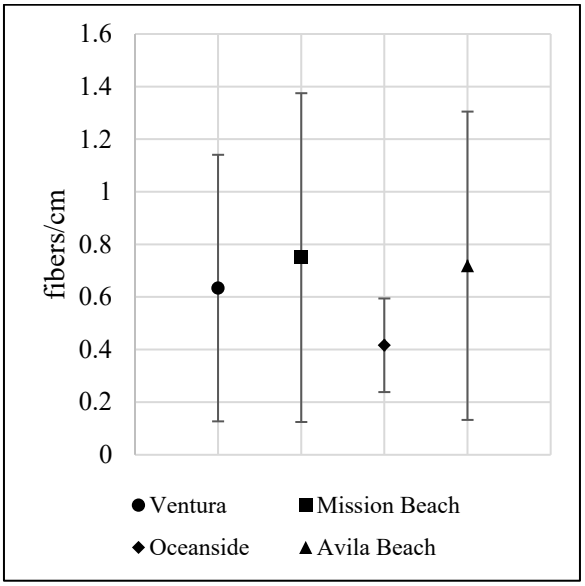

Figure 5b. *Mussels collected from beaches.*

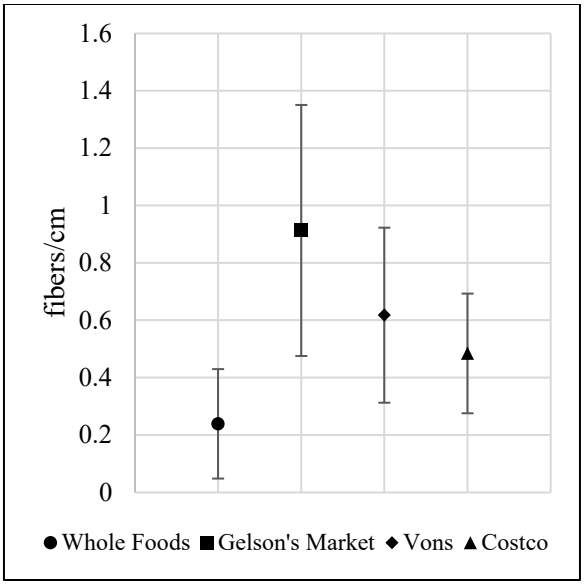

Figure 5c. *Mussels collected from supermarkets.*

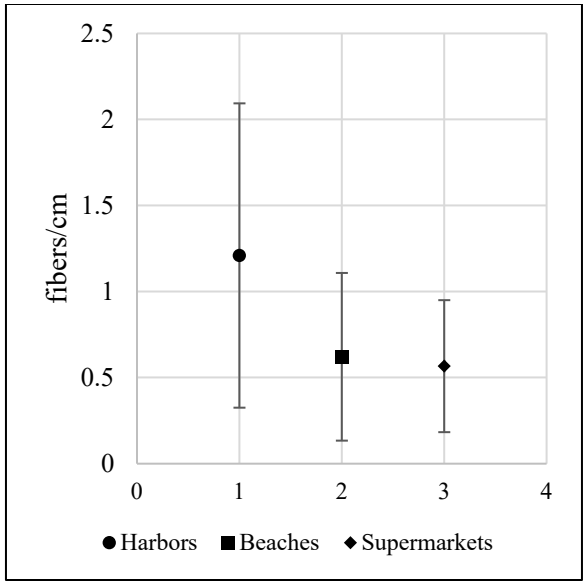

Figure 5b. *Mussels collected from the three site types.*

Figure 5. The average number of microfibers per shell length in wild mussels collected from harbors and beaches, and farmed mussels collected from local supermarkets. Bars represent mean value +/- Standard deviation. Outliers have been removed.

The total number of microfibers on each filter was divided by the total weight of organic matter to obtain the number of microfibers per gram of soft tissue and microfibers per centimeter of shell. The number of microfibers varied from 0.0 to 13.5 fibers/sample (**Figure 3d**), 0.0 to 6.30 fibers/g ww (**Figure 4d**), and 0.0 to 3.88 fibers/cm (**Figure 5d**). At the harbor sites, mussels contained on average 6.04 fibers/sample (**Figure 3a**), 1.38 fibers/g ww (**Figure 3b**), and 1.21 fibers/cm (**Figure 3c**). The beach sites contained 3.62 fibers/sample (**Figure 4a**), 0.55 fibers/g ww (**Figure 4b**), and 0.762 fibers/cm (**Figure 4c**). The farmed sites contained 3.21 fibers/sample (**Figure 5a**), 0.56 fibers/g ww (**Figure 5b**), and 0.652 fibers/cm (**Figure 5c**). An outlier was removed from the Costco and Ventura beach sites.

DISCUSSION

Microfiber pollution was widespread in both wild *M. californianus* and farmed *M. edulis* samples. The abundance of microfibers was significantly higher in the harbor sites (6.04 fibers/sample) than the beach sites (3.62 fibers/sample). There are multiple factors that could have influenced microfiber concentration levels, such as varying marine environments, proximity to nearby human activity, and sources of effluent discharge.[19] Harbors are known to have higher rates of accumulation than rocky shorelines due to their low energy environments where particles are often deposited as sediment.[20] Meanwhile, exposed rock jetties are characterized by their high energy environments where particles often remain in suspension.

Bivalves collected near commercial or industrial activity, as well as sheltered bays and harbors, have an increased probability of microfiber uptake.[19] The harbors and beaches examined were located near large sectors of commercial and residential activity, where the average population is 73,887 people and 83,635 people, respectively.[21] Due to large population pressures, there are many potential sources of residential and commercial discharge. For example, wastewater often flows directly into coastal bays through routes such as construction debris, grease clogs, root intrusion, and structural failures of pipes.[22] In Newport Beach, 14 sewer systems failed from 2013 to 2018, spilling at least 6,400 gallons of wastewater into Newport Bay and the open ocean.[22] When compared to the other sites, the direct discharge of greywater may have significantly increased the number of microfibers in Newport Bay.

We expected the farmed mussels to contain more microfibers than the wild mussels. There was a significant difference between the supermarket and harbor mussels examined, but not between the supermarket and beach mussels. Similar population pressures and environmental factors may have resulted in the insignificance. The supermarket mussels collected from Whole Foods, Gelson's Market, Vons, and Costco were cultivated in Carlsbad, Santa Monica, and Pleasanton, California and Coupeville, Washington, respectively. The microfiber input in these regions, where the average population is approximately 72,383 people,[21] would be similar to the beach sites examined. The mussels also likely had similar culture conditions to the beach samples. Farmed mussels are often cultured in coastal areas and grown on ropes suspended into the water column.[22] These mussels feed on algae naturally presented in the seawater and as a result, are exposed to any pollutant in the environment, including microfibers and other anthropogenic particles.[23]

The difference in *Mytilus* species may have also affected the number of microfibers accumulated and retained. Although the organisms are closely related, *M. californianus* is a larger species, usually containing twice as much dry meat as *M. edulis*.[24] However, there was no correlation between the number of fibers and weight or shell length. This suggests that local pollution has more of an impact than mussel size or species.

The average number of fibers we identified per sample (4.47 fibers/sample) and per gram of organic matter (1.02 fibers/g) was consistent when compared to the amount reported in other studies. For example, 0.26-0.51 fibers/g were identified in De Witte *et al.*, 2014[5] and 2.1-10.5 items/g were identified in Li *et al.*, 2015.[17] However, concentrations recorded might be overestimated due to the limited contamination prevention protocols completed in this study. This could have a considerable impact on the procedural contamination levels. For example, airborne fibers in the laboratory, water supplies, and hydrogen peroxide could not be ruled out, which might have contaminated the samples. Further work, equipment, and methodological checks are needed to limit contamination, such as procedural blank filters and Tape Lift Screening.[23] The short duration of the project and the limited data collected may have affected the concentrations of microfibers recorded. Additional data could reveal a significant difference between the wild and farmed samples or an increase or decrease in the concentrations of microfiber contamination in these southern California locations. It could also reveal a correlation between the number of fibers and weight or shell length of the mussels.

Despite for the limitations of this study, microfibers were observed on 99.98% of the filter examined, indicating widespread microfiber pollution and uptake by mussels in these locations. The presence of microfibers in the visceral mass indicates ingestion of these plastics. In numerous studies, microplastics have caused physical damage to the organism examined.[2, 4, 25] For example, microplastics have induced inflammatory responses and decreased lysosomal stability in bivalves, revealing associated stress, a toxicological response, and pathological changes.[24] In addition, the accumulation of microfibers inside the bivalves increases the probability of plastics transferring to higher trophic levels. Field investigations also have shown that microplastic abundance in mussels is correlated to the range of human activity in their surrounding environment.[6] Thus, microfiber pollution observed in the mussels reflects local levels of contamination in the water and sediment and indicates that bivalves can continued to be used as a bioindicator of marine pollution.

CONCLUSIONS

As the global demand for plastic increases, the number of organisms ingesting microplastics will too. Microfibers are more ubiquitous than once thought, prevailing in marine environments, the Artic,[26] and the most isolated areas in the United States, such as national parks and national wilderness areas.[27]

In our oceans, microplastics could detrimentally affect ecosystems and human health, causing demographic and food and prey shifts, taxa specific vulnerability, and hazards to human food.[3] Seafood consumption represents one of the most common pathways for human microplastic exposure.[28] Along with the continuous growth of plastic, seafood consumption has more than doubled to over 20 kg per capita per year in past 50 years.[29] With this increase in seafood consumption, microfibers may pose more of a threat to food safety.

Although in current literature there is limited data on the toxicity of microplastics in humans, it is likely that microplastics absorb monomers, additives, and POPs, enhancing the toxicity of these plastics.[28] In addition, preliminary research has demonstrated many concerning impacts microplastics may have on the human body, such as enhancing inflammatory responses and disrupting the gut microbiome.[19]

However, the differences in techniques of isolating and identifying microplastics makes it difficult to compare the levels of pollution between studies. The creation of comprehensive models, along with uniform and more effective methods, should be developed in the future. This could aid in determining the toxicological risk microplastics pose to bivalves, humans, and other organisms consuming these plastics.

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PRESS SUMMARY

Microfibers are an emerging threat to aquatic habitats and human health worldwide. These microscopic pieces of plastic, typically defined as less than 5 mm in diameter, are a type of microplastic that originates from synthetic clothing, such as polyester and nylon. Often through the process of machine washing, fiber fragments are expelled into the wastewater and are eventually deposited into the environment. Filter feeder organisms, such as mussels, ingest these pollutants, and in turn, are consumed by other organisms, including humans. There has been little examination of the mussels located in the harbor, coastal beaches, and supermarkets of southern California. In this study, we quantified the number of microfibers ingested by mussels. We discovered microfibers in 99.98% of the mussels examined, indicating widespread microplastic pollution and uptake by mussels in these locations.

A Brief History and Overview of Existential-Phenomenological Psychology

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ABSTRACT
This article surveys the background and theory of the existential-phenomenological approach to psychology, with a particular focus on its reception in the United States. The article begins with a discussion of what exactly existential-phenomenological psychology is, including the theories underlying this approach and its basic practices. The article then discusses how the approach developed, including its roots in the philosophies of existentialism and phenomenology, its first appearances in Europe, its globalization, and finally its arrival in the U.S. The article then discusses struggles that the existential-phenomenological movement in psychology is currently facing and the concerns of those involved in the movement for its future. Finally, the article closes on a summary of all the information presented as well as of the contributions to the field of psychology that it and the existential-phenomenological movement can make.

KEYWORDS
Existentialism; Phenomenology; Psychology; United States; Existential Psychology; Phenomenological Psychology; Existential Psychotherapy; Philosophy of Psychology

WHAT IS EXISTENTIAL-PHENOMENOLOGICAL PSYCHOLOGY?

Existential-phenomenological psychology is an approach to psychology in all of its various subfields, although most prominently clinical and counselling psychology. This approach, which various regions throughout the world have come to recognize,[1] has its roots in the continental philosophies of "existentialism" and "phenomenology." These two schools, though arising from different roots, soon became closely allied and now often come in tandem, which is reflected in the fact that existential psychology and phenomenological psychology are commonly viewed as the same thing. They are, however, two different schools of thought that simply tend to concur, and thus a discussion of what exactly each school is and the differences between the two of them is important to show how each may operate on their own, separately from the other. One should note that each of these terms represents a diversity of approaches within each school, and a single unifying definition for either "existentialism" or "phenomenology" is difficult due to the many disagreements in how each term should be defined. However, this paper will present the definitions seen by the author to most encompass all of the perspectives within each school.

The school of existentialism represents most fundamentally a philosophy and theory of human nature that attempts to turn its focus away from the normal focus of most philosophy and psychology on trivial, everyday concerns and toward a focus on deeper, more profound problems of human life.[2-4] What these "profound problems" of human life are vary from one existential thinker to another; for instance, Medard Boss names them as human relationships with space, with time, human beings' acting through their body, the necessity for human beings to share a world with others, the necessity for human beings to constantly live in a mood, human beings' living in a historic context, and human beings' relationship with their own mortality.[5] Yalom, on the other hand, specifies the relationship between humans and their freedom plus the consequent responsibility for their actions, existential isolation, meaninglessness, and mortality as the fundamental "existential issues" with which one is concerned throughout their life.[6] Both of these theorists agree, however, that each of these issues represent more foundational problems of life than are commonly the focus within psychology, and that it is thus more important to gain an understanding of them. As can be seen, existentialism, both within the fields of philosophy and psychology, prefers to study more personal aspects of humanity than is the status quo in most other schools within these disciplines. Thus, existentialism refers primarily to a theory of what is important to understand about human beings and, in psychology, what topics a study should cover.

Phenomenology, on the other hand, is less of a theory of what *should be* studied, and more of a theory of *how to* study things. Phenomenology represents an attempt to move away from what most figures within the field call "natural science" approaches to studying human beings. These are the traditional scientific practices of attempting to observe phenomena and events from the

outside as tangible, measurable, and predictable occurrences. Phenomenologists choose instead to point toward a study of human experience as a phenomenon in which the "within" and "without" are indistinguishable, and the "apparent within" of human subjects (i.e. their subjective experiences) is given equal attention to the "apparent without" (i.e. their observable behaviors).[7] Phenomenology is often referred to as the study of "subjective experience", which is not far from the definition of phenomenology intended by most of the prominent figures of the school, but it can be misleading due its implications of viewing humans as subjects separate from the objects they encounter. In fact, phenomenology represents an attempt to transcend the split between subject and object that is so inherent in much modern scientific research, stemming from the Cartesian tradition of studying nature. The existential-phenomenological psychologist Emmy van Deurzen describes phenomenology as a methodology that "sets out to study subjectivity objectively and objectivity subjectively, whilst addressing the whole of human conscious experience in its complexity."[8] Phenomenology should therefore not be confused with such methods as introspection, which tend to isolate the human subject from their world.[3]

These two disciplines, as mentioned above, have had a history of close alliance to each other and are often studied reciprocally. This is most accredited to the philosopher Martin Heidegger, who, in his breakthrough work *Being and Time*,[9] was the first to unite these two traditions into one study of ontology—or being—which inspired much of modern phenomenological research. Since the publication of *Being and Time*, the most customary practice within these two traditions was to combine them into one tradition, particularly in psychology. This resulted in their becoming nearly, although not entirely, identical to each other. Though they are often united, they remain their own schools of thought, and they may still occasionally be applied apart from each other. Most notably, phenomenological research methods are occasionally applied to the study of more commonplace subjects within psychology. Some scholars have stated that all existential psychology is a form of phenomenological psychology, but that the reversed statement isn't true;[10] however, recent movements in psychology, such as the push for an "experimental existential psychology",[11] seem to discredit this statement by developing an existential theory in psychology that does not use phenomenological methods of study. Despite their occasional separation from each other, this paper will focus specifically on the movements in psychology that combine the two traditions, and their applications both to psychological research as well as more applied areas in psychology (such as therapy or clinical interviewing). Please note that, as a mere survey of this intellectual discipline, this article will not serve as a comprehensive account of the history of the movement but will only serve as an introduction to those relatively unfamiliar with existential-phenomenological psychology.

THE HISTORY AND DEVELOPMENT OF EXISTENTIAL-PHENOMENOLOGICAL PSYCHOLOGY

The philosophical roots

Through the course of the nineteenth century two thinkers who had paradoxically never become acquainted with one another's works emerged in the Western world. Each of these thinkers had radical ideas that profoundly impacted many of the same groups of people. These thinkers were the Danish philosopher Søren Kierkegaard[12-14] and the German philologist turned philosopher Friedrich Nietzsche.[15-18] On the surface, these two thinkers would appear to have nothing in common with one another. Kierkegaard's works were firmly rooted in his Protestant faith—so much so, in fact, that his philosophy could be described as a kind of theology. Nietzsche, on the other hand, was fiercely atheistic, and placed himself in stark opposition to Christianity. However, upon a closer glance, one can easily find a spirit in each thinker's work that they shared. Most notably, both thinkers opposed the tendency in their times to turn one's focus away from the concrete, lived realities of human beings and towards abstract principles that exist outside of human experience. In Kierkegaard's case, these were the principles of a scientific and technological revolution which made human beings anonymous and made objects out of people, failing to pay proper attention to the significance of the human individual subject. In Nietzsche's case, this was a religion which reviled all human desires as evil and put its faith into a God assumed to be inherently better than humanity; a God which Nietzsche himself claimed to be dead in a notorious passage.[15] Also important is that both thinkers were fiercely critical of the tendency they observed in humans to lose themselves in trivial, everyday pursuits, and in mindless conformity to the masses. Kierkegaard and Nietzsche sought, in their philosophies, to bring concern back to the deeper questions of an individual person's life, thus providing the foundations for existential philosophy.

Many years after Kierkegaard, and shortly after Nietzsche, Edmund Husserl[7, 19, 20] founded the school of phenomenology—a school that was at that point not yet connected to existentialism. Husserl found fault with the accepted methods of studying the world during his time and developed a philosophy that would eliminate some of the biases that were inherent in these methods. Husserl was inspired by a series of lectures by Franz Brentano on the concept of "intentionality," or the tendency of human consciousness to direct itself towards specific objects and apprehend them as they appear to this consciousness.[A, 2, 7] This led Husserl to propose a philosophy that sought to study phenomena "as they appear,"[7] naming this method "phenomenology". Husserl borrowed this term from other philosophers who had used it before, such as Immanuel Kant and Georg Wilhelm Friedrich Hegel, but Husserl was the first to establish "phenomenology" as its own discipline. Husserl sought to design a method of analysis in which, rather than analyzing the phenomena that one encounters, one rather analyzes their state of consciousness when encountering these phenomena to better understand the phenomena as they present themselves without bias. This called

for a suspension of the preconceptions that one carries from their personal and cultural experiences—a process which Husserl named "bracketing." When applying the concept of "bracketing," one must essentially examine the assumptions which they make when first exposed to a phenomenon. Upon identifying these assumptions, one is encouraged to set them aside for the time being in order to better understand the phenomenon simply "as it appears" and without bias. As one is able to identify and "bracket out" more such assumptions, one is assumed to be gaining a better understanding of the phenomenon which they are encountering. In particular, Husserl placed much emphasis on bracketing out the "natural scientific" attitude towards phenomena, referring to the Cartesian-rooted tradition of separating the phenomenon from its background and even from oneself—it should be recalled that phenomenology rejects the split between "subject" and "object." This concept of bracketing is significant to the various psychological research methods developed in the name of phenomenology; primarily qualitative research methods which require one to "bracket out" one's own assumptions and biases regarding the topic of interest in a study so that one may better understand the experiences of one's participants.

Martin Heidegger, one of Husserl's students, was familiar with all of the thinkers mentioned above, and synthesized their thinking into a "phenomenological ontology" in his esteemed tome, *Being and Time*,[9] as mentioned above.[B] In this work, Heidegger does not necessarily seek to present a study of *human* being specifically, but rather an analysis of existence at large. However, *Being and Time* still contained many valuable insights into human nature because of its grounding in ontology, or the philosophical study of being. Most notably, Heidegger discusses his concept of "*Dasein*" (literally: being-there, usually interpreted to mean "presence"), which refers to human consciousness and its drive to make meaning out of the world and the person's own relation to the world. In Heidegger's words, "Dasein is an entity which... in its very Being, that Being is an *issue* for it... Dasein, in its Being has a relationship towards that Being—a relationship which itself is one of Being."[9] Heidegger conceptualized the human "Dasein" as an entity which must constantly reflect upon its own Being in relation to the Being of the world in which it exists, thus providing a foundation upon which human psychology could be studied and understood. Heidegger is thus commonly credited with being the first existential phenomenologist, although he rejected being ascribed such titles as "existentialist" due to their misleading tendency to label his philosophy (which can, and has, resulted in much confusion over what exactly can be considered "existentialism.") Nevertheless, Heidegger very well may be the philosopher who has had the most influence on the existential-phenomenological approach to psychology, and much of the movement's assertions should be credited to their roots in his thinking.[21]

Aside from spearheading the movement of "existential phenomenology," however, Heidegger made yet another major contribution to the tradition of phenomenology: he highlighted the importance of hermeneutics, or the practice of understanding texts and dialogue through interpretation, to phenomenological investigations. Where Husserl's phenomenology attempted to remain strictly descriptive, seeking to understand phenomena as they present themselves without the preconceptions provided to one by cultural, historical, and linguistic preconceptions, Heidegger understood humans as fundamentally cultural beings, who always come from historical and linguistic backgrounds that both facilitate one's understanding of a phenomenon and limit such an understanding. Heidegger also saw humans as beings that always have predispositions as a result of their earlier experiences: "Interpretation is grounded in something we have in advance—in a fore-having."[9] Thus, understanding a phenomenon "as it appears" cannot, in Heidegger's philosophy, end at a mere description of the phenomenon, but must necessarily include an interpretation of this description in terms of the personal and cultural background of the person providing the description. Where Husserl saw the task of the phenomenologist as one of "bracketing out" one's biases, Heidegger acknowledged that a complete bracketing of one's biases is not possible, and proposed instead that one could use their own assumptions to facilitate their understanding of a phenomenon while seeking to engage in discourse with those who carry alternate assumptions. This method of acknowledging the role which one's assumptions play in their understanding a phenomenon while seeking to balance this with the assumptions of others is known as the "hermeneutic circle."[9] This approach to phenomenology provides the foundations of the "hermeneutic" phenomenological method, in contrast to the "descriptive" or "empirical" method rooted in Husserl's thinking.[22]

Heidegger's work was heavily criticized, however, for some of its excessive individualism. One should recognize that Heidegger had set out to correct some of the individualism overabundance found in Kierkegaard and Nietzsche's works, positing every existence as a "being-in-the-world" which must always exist in relation to their world. Heidegger also presented the concept of a "care structure" in human consciousness, which does involve the recognition of one's responsibilities for others. Nevertheless, Heidegger's philosophy still seemed to prioritize an individual's reflection on their own existence, with other people being primarily encountered as obstacles. Limited room is given for empathic reflection on the other's existence as one reflects on their own existence. Such issues in Heidegger's philosophy became even more relevant when Heidegger joined the National Socialist Party, revealing his anti-Semitic biases. Suddenly, Heidegger's concept of "*Dasein*" did not seem to apply to people of Jewish heritage, which presented a severe flaw in Heidegger's thinking. This led to various re-developments of Heidegger's philosophy among his students, including the Jewish existentialist Emmanuel Levinas. Levinas refined Heidegger's thinking to include *Dasein's* reflection on both its own existence and that of others in his concept of the "*Face*," or the other's assertion of their own

subjectivity onto the individual. This "Face" forces one to recognize the "Other" as also embodying *Dasein*.[23] Such contributions as is found in Levinas' and others' (such as Hannah Arendt's and Herbert Marcuse's) re-inventions of Heidegger's thinking helped pave the road to the application of existential phenomenology in therapy—a situation in which the therapist and the client must both recognize each other as embodying *Dasein*.

Very soon after the time of Heidegger and his students' works, the ideas of these thinkers began to gain interest among a group of French philosophers. Among the most famous of these philosophers were Jean-Paul Sartre[24, 25] and Simone de Beauvoir.[26, 27] Sartre was, in fact, the first thinker to place the name of "existentialism" onto his philosophy, and included Kierkegaard, Karl Jaspers (see below), Heidegger, and various other thinkers in his list of people who could also be considered a part of the movement,[25] even though none of these thinkers explicitly used the term to describe their own philosophies. Sartre's major work consisted primarily of a series of responses to all of these thinkers, expanding upon their ideas and, in some cases, refining the aspects of their philosophies that he believed to fall short of reality. The term "existentialism" is most attributed with Sartre, and it is Sartre's take on the philosophy that most commonly comes to people's minds when they hear the term. This has caused much confusion as to what "existentialism" is, as Sartre's philosophy is radically different from many of these authors who did not explicitly use the term and even occasionally rejected it. To most existential psychologists, however, any philosopher who sought to focus on the deeper concerns of human existence over the more trivial concerns of it could be considered a part of the movement. Some propose using such terms as "existential philosophy"[2] or "philosophy of existence"[28] instead of "existentialism" to refer to the movement. This is intended to both respect some thinkers' wishes not to be placed under a restrictive label while still acknowledging their influence on the existential movement in psychology. This is thus the definition for "existentialism" (or "existential philosophy," if preferred) that will be used in this paper.

Jean-Paul Sartre's most notable contribution to the application of existential phenomenology in psychology is his famous (and somewhat controversial) statement that "existence precedes essence." This seemingly esoteric phrase carries a surprisingly straightforward meaning: it refers to Sartre's idea that human beings are not given a prescribed purpose, or "essence", but are rather tasked with creating this "essence" for themselves. Sartre saw humans as fundamentally free creatures and believed that there are essentially no pre-deterministic forces that shape a person's actions, decisions, or identity.[24] While this position may seem extreme at first glance, Sartre was, in reality, ready to acknowledge that there were limitations placed upon human freedom. Drawing upon Heidegger, for instance, Sartre did acknowledge that human beings are not able to choose which cultural and historical context in which they are born, nor various other aspects of their conditions. However, according to Sartre, humans retain the freedom to respond to these limitations in any number of ways and are thus still fundamentally free. This freedom, however, comes with the weight of responsibility which one has for their own actions, and ultimately for the entire world.[25] Freedom, then, is not necessarily praised as a blessing as it is in other philosophies, but rather is seen as a given aspect to human existence which all humans must face, and which presents human beings with both liberties and challenges.

Sartre also contributed to the existential-phenomenological movement in psychology by formulating his recreation of psychoanalysis, which he terms "existential psychoanalysis." This system re-established the foundational ideas behind psychoanalysis to place more emphasis on existential concerns than on the aspects of humanity on which classic psychoanalysis focuses, such as sexuality or overcoming an inferiority complex.[24] It also attempts to look for the "projects" which one undertakes for their existence, with "projects" referring to the purposes or ideals that one sets out to fulfill. Existential psychoanalysis sees these "projects" as a defining feature of one's life and the meanings which one creates in their psyche.[24] These ideas particularly influenced certain existential psychologists who synthesize existential-phenomenological practice with psychoanalytic therapeutic techniques, such as Rollo May.[29]

Unfortunately, Sartre's fellow author, Simone de Beauvoir, tends to be overlooked in comparison to him, despite her also remarkably high influences on the movement of existentialism. Sartre and de Beauvoir influenced each other's work a great deal, and de Beauvoir proposed many radical ideas in her philosophy that the existentialists before her had not yet dared to make. One of her greatest contributions was applying existential concepts to the movement of Feminism, as she used Sartre's mantra of "existence precedes essence" as a basis for her critique of gender roles in her notorious quote: "One is not born but becomes a woman."[26] This greatly influenced the Feminist movement as well as the movement for transgender rights, and de Beauvoir is partially responsible for developing the idea of the sex-gender split with her emphasis on distinguishing between the biological givens of sex and the culturally created prescriptions of gender.[30] De Beauvoir's philosophy was also known to be more explicitly prosocial than Sartre's, as de Beauvoir frequently discussed the necessity of contributing to the welfare of others in order to achieve true freedom.[27] De Beauvoir also expanded upon Sartre's views of social relations to include not only conflict as a fundamental aspect of social confrontations but also mutuality and reciprocity.[2]

Though not listed in quite as much detail here, many other figures have also been influential on the development of existential and phenomenological philosophy. For instance, Martin Buber proposed a distinction between "I-Thou" experiences, or

experiences in which two people meet each other as equally present entities and are open to shared experiences, and "I-it" experiences, in which people encounter others with attitudes of indifference and treat others much like objects.[31] These descriptions of such experiences gained Buber wide credit as a major contributor to existential thought. Also important is Karl Jaspers, who, as shall be seen below, was originally a psychiatrist who then turned to existential philosophy[C] to gain a fuller understanding of humanity. Maurice Merleau-Ponty was also well known for his contributions to existential-phenomenology and was particularly known for refuting the distinction between mind and body that was present in most thinkers from Descartes onwards. [32, 33] Many other figures were significant, of course, but to attempt to list them all would be difficult to do in a single article.

Existential-phenomenological psychology's beginnings in Europe

At around the same time that the thinkers listed above were developing "philosophical anthropologies"[D] in the form of their "philosophies of existence", many psychiatrists and psychologists in Europe began to take an interest in their ideas and apply them to a "scientific anthropology" of their own design. One of the first figures to do this was the Psychiatrist Karl Jaspers, who helped to pave the road on which existential-phenomenological approaches to psychology and psychiatry could come into existence. Jaspers earned his degree in Psychiatry from the University of Heidelburg; however, feeling disenchanted with the incomplete perspective on humanity prominent in psychiatric study, he then turned to philosophy to assist in providing a more complete picture of humanity for psychiatric study. The most prominent work in which Jaspers used existential philosophy to supplement psychiatry was his two-volume tome *General Psychopathology*.[34] In this work, Jaspers introduces the practices of psychopathological study and also gives his critique of some of the traditions in the field. *General Psychopathology* is a breakthrough work in the field of psychiatry which represents one of the first efforts to inform psychiatric and psychopathological study of the issues expounded upon by existential philosophers. Eventually Jaspers even ended up becoming less of a psychiatrist and more of a philosopher, giving lectures on philosophy and publishing philosophical works rather than applying himself to work with clinical cases.[2, 28]

Another important contribution of Jaspers' was his introduction of phenomenology as a research method in the field of psychopathology. Jaspers was one of the first in any of the fields of psychiatry, psychology, or psychopathology to begin arguing for the necessity of phenomenological research in these fields.[35] He was also one of the first to begin using it. *General Psychopathology* even dedicates an entire chapter to describing some of the phenomenological research conducted up to the time of the work's publication on various abnormal psychic phenomena. This application of phenomenological methods to research and analysis in psychiatry then influenced various psychiatrists writing after him, such us Eugene Minkowski, Erwin Straus, and Viktor von Gebsattel.[E, 36]

However, Jaspers' approach was not yet truly "existential psychiatry," as his work in psychiatry was not yet a thorough dedication of his studies to understanding human confrontations with existential dilemmas—rather, Jaspers' work took more of a flavor of a psychiatry that allowed existential philosophy to inform its practices to some extent. This fact is even further emphasized by the fact that Karl Jaspers eventually began to give up on psychiatry and become more of a philosopher, which only further contributed to the split between scientific psychology and philosophy. Rather than Jaspers, the first figures to synthesize existentialism with the fields of psychiatry and psychology were those in the school of *Daseinsanalysis*.[F] This movement was spearheaded by the psychiatrist Ludwig Binswanger,[G] whose work was one of the first to begin applying phenomenological research methods not only to understanding psychopathological phenomena, but also to concerns of human existence. By observing how his clients related to the world around them and attempted to find meaning in it, Binswanger laid the groundwork upon which all of existential-phenomenological psychology would from then on be based.[36] Binswanger first referred to his school of psychiatric study as "phenomenological anthropology," but then later termed it "Daseinsanalysis," directly referencing the Heideggerian concept of human "Dasein."[H] Binswanger was thus the first to give his psychiatric approach a name with a distinctly existential flavor, in contrast to Jaspers' more universal approach to psychiatry.

Following in Binswanger's footsteps was the psychiatrist Medard Boss.[5] Aside from his roots in Binswanger's thinking, Boss also studied with Martin Heidegger for many years and based much of his approach to psychiatric work on Heidegger's ideas.[2, 3] Boss, like Binswanger, referred to this approach as "Daseinsanalysis" in reminiscence of Heidegger. Boss continued Binswanger's dedication to studying psychiatric patients' encounters with their world and attempts to make meaning out of this world. However, Boss was even able to develop this practice further than Binswanger, becoming the first figure in the history of psychology and psychiatry to develop a specifically existentially-oriented psychotherapy. This earned Boss the honor of becoming one of the most influential figures in the entire history of existential-phenomenological psychology. He is especially revered in Europe, where he is upheld as the single most influential founder of existential-phenomenological approaches to psychology for the region.[3]

Daseinsanalysis is frequently seen as an attempt to integrate existential thought into psychoanalysis and does indeed involve this to some extent. In reality, though, Daseinsanalysts tended to be highly critical of much psychoanalytic thinking, especially classic Freudian psychoanalysis.[5, 36] Binswanger and Boss themselves would likely have described their approach more as an analysis of how human beings relate to their world, and how this relationship with their world influences their thoughts, feelings, actions, etcetera. Both thinkers had received some experience in psychoanalysis before turning to "Daseinsanalysis" and, having seen psychoanalysis in action firsthand, both were aware of some of the dangers of using this approach. This would set in motion a dilemma in the movement of existential-phenomenological psychology that to this day has not been resolved; this being the dilemma over how much influence psychoanalysis should have over existential-phenomenological psychology.

Daseinsanalysis, however, was not the only variant of existential-phenomenological psychology in existence. Many other schools of existential-phenomenological thinking also began to emerge after Daseinsanalysis rose into prominence. Another of the most notable schools of existential-phenomenological thinking was Logotherapy, conceived by the Austrian psychiatrist Viktor Frankl. Frankl developed this therapeutic approach largely in response to his experiences in a concentration camp during the National Socialist regime. During his time in the camp, he noticed that it was the people who were able to find a meaning in what was happening to them, even if it seemed meaningless, who were best able to survive all of the grueling treatments that they suffered at the hands of the SS. At the end of World War II, after finally being freed from the concentration camp, Frankl began writing his signature work, *Man's Search for Meaning*,[37] which would come to be seen as the key text for Logotherapeutic practice and would rise to a prominence even rivaling that of Daseinsanalysis. In *Man's Search for Meaning*, Frankl presents his view of humanity as a species which is constantly tasked with giving their life a meaning. People who can find a meaning for each experience they have can withstand nearly any struggle, even the most painful and damaging, with resilience. Thus, Frankl's practice of Logotherapy largely involves encouraging clients to find meaning within their circumstances, thus making these circumstances more bearable and allowing the client to live a more fulfilled life. While Frankl did not emphasize ideas of inherent meaninglessness in life as much as other existential thinkers, such as Sartre[24, 25] and Yalom,[6] he did acknowledge that it was perhaps more apt to encourage people not to inquire about the meaning of life but rather to perceive the universe as asking them what would be the meaning of *their* life.[37]

Writing close to the same time as Frankl, R.D. Laing began developing his own existential approach to psychotherapy in the United Kingdom. Laing, a psychiatrist, was highly influenced by a movement in the UK during the time of his writing which the psychiatrist David Cooper called "anti-psychiatry," although many of his colleagues (including Laing) were less certain about using this label. This movement was characterized by a renewal of skepticism in the traditional teachings of psychiatry. In the case of Laing and Cooper, this took on a particularly existential tone, with both figures being highly influenced by Sartrean ideas and taking up Sartre's call to rebel against those authorities who abuse their power. Laing and Cooper believed that many psychiatrists, upon being put in a place of power over their patients, abuse this power to invalidate their "madness" instead of truly recognizing the necessity of this "madness" for the patients. Laing began developing a radical psychiatric approach that saw the goal of therapy and treatment not as curing psychiatric disorders, but rather engaging with people using their seemingly "mad" state and reciprocally getting them to engage in these states. He and Cooper notoriously argued that it may be the patients, in fact, who were the most sane, as their psychiatric "disorder" may simply be their breakthrough from the ordinary delusions that "normal" people allow themselves to have.[2] Laing's existentially oriented approach to psychiatry eventually mellowed out over the course of his career from this rather extreme form of existential therapy; however, he never put an end to the trademark existential practice of entering into his patients' worldviews (rather than basing his treatments off of his own psychiatric worldview) and zealously encouraging them to confront the reality of their situations directly. Laing's novel approach to therapy would go on to influence an entire school of existential-phenomenological research and therapy known for most of its history as the *British School of Existential Psychotherapy,*[1] developed by such figures as Emmy van Deurzen, Ernesto Spinelli, and Hans Cohn.[2]

In more recent years, existential-phenomenological psychology has continued to thrive across the continent of Europe. Indeed, recent research suggests that Europe, the very birthplace of existential-phenomenological psychology, is the region of the world in which existential-phenomenological psychology remains to have the greatest influence.[1] Existential-phenomenological psychology increases in interest on the continent of Europe every year and constantly has new developments. Perhaps the most important development in the past few decades has been the establishment of the *Society for Existential Analysis* in London in 1988.[38] This organization, which the highly influential therapist Emmy van Deurzen founded, was formed as a dedication to furthering the development of existential-phenomenological psychology around the world. The society is known for its variety of events and activities, such as discussion forums, conferences, and seminars.[39] Most notable of all of the society's activities, however, is the *Journal of the Society for Existential Analysis*. This is the society's peer-reviewed, academic journal, which is dedicated to allowing existential-phenomenological practitioners around the world to engage in the major discussions of existential-phenomenological psychology. It also allows existential-phenomenological psychologists to publish original research and other major contributions related to the field. This publication is perhaps the most important worldwide platform for academic work in existential-phenomenological psychology, making the *Society for Existential Analysis* a central organization for the movement.[40]

The founder of the *Society for Existential Analysis*, Emmy van Deurzen, is a particularly prominent figure in modern existential-phenomenological psychology, and one could indeed argue that she is the current most influential author on the topic around the world and especially in Europe. In particular, van Deurzen, along with other major figures in the "British School of Existential Psychotherapy" is the source of much influence over existential practice in Australia and in almost all of Europe, excluding only central Europe.[2] Emmy van Deurzen is companioned with such psychologists as Erik Craig, Alfried Längle, Digby Tantum, Bo Jacobsen, Martin Adams, and countless others in keeping the existential-phenomenological tradition alive in Europe throughout the modern era.

Existential-phenomenological psychology's worldwide influence

After its initial development in Europe, existential-phenomenological psychology soon began to find a place of interest for cultures across the globe. Varying parts of the world have begun to be adopt Existential-phenomenological psychology and its various sub-movements, many of whose cultural contexts are so different from Europe that one could easily never have expected these places to take any interest in the approach. In a study by Correia, Cooper, and Berdondini,[1] European institutions for existential psychology only constituted about 52.3% (*n*=67) of the 128 total existential psychology institutions found, leaving around 47.7% (*n*=61) of these institutions to the rest of the world. The number of individual European practitioners who participated in the study also only constituted about 51.2% (*n*=572) of the whole worldwide sample of 1,117 practitioners.

After Europe, the region of the world with the highest influence of existential-phenomenological approaches to psychology was Latin America, with 29.7% (*n*=38) of the total number of institutions represented and 26.2% (*n*=293) of the total number of practitioners participating in the study.

Australia and North America had very similar characteristics to each other in terms of the influence of existential-phenomenological psychology in these regions. However, North America had a slightly higher number of institutions than Australia at *n*=15, composing 11.7% of the total sample (*n*=3 and 2.3% of the total sample for Australia). North America also had slightly more practitioners than Australia at *n*=112, composing 10% of the sample (*n*=85 and 7.6% of the total sample for Australia).

Asia and Africa showed the lowest influence of existential-phenomenological psychology. Asia had about 3.1% of the institutions discovered in the study (*n*=4) and 4.7% of the practitioners discovered (*n*=53). Africa had 0.8% of the total number of institutions (*n*=1) and 0.2% of the total number of practitioners (*n*=2).

As can be seen, existential-phenomenological psychology has expanded from its original seclusion in Europe to a vast array of places around the world, although it has been more successful in certain regions than in others.

Existential-phenomenological psychology's reception in the United States

Eventually, the movement made its way into the United States. The reception of the movement in this nation has been somewhat ambivalent. On one hand, it certainly has enjoyed some success in the U.S., having more influence here than in certain other areas such as Asia and Africa, or even Australia. On the other hand, it has not been nearly as successful in the U.S. as it has been in its birthplace of Europe or even in Latin America. In Correia et al.'s study mentioned above,[1] the U.S. was found to have 8.6% (*n*=11) of the total number of institutions in the study as well as 9% (*n*=101) of the total number of practitioners. This seems to imply that while existential-phenomenological psychology has found its way into the U.S., it is still developing here as a movement and struggling to gain prominence in the nation.

The first to bring existential-phenomenological psychology into the U.S. seems to be the esteemed therapist Rollo May.[29, 36, 41-45] May began applying the ideas of many of the existential thinkers mentioned above to his therapeutic sessions and found that this approach to therapy worked well for his clients. Seeing the efficacy of existential-phenomenological psychology in action, May began calling for an adoption of more existential ideas into the U.S.'s system of psychology as a means of replacing what he perceived to be a serious reductionistic tendency in most American psychology during his time. May especially pointed to the dominance of such movements as behaviorism and cognitive approaches to psychology and therapy as major examples of this reductionistic tendency.[29, 44, 45] May believed that the ideas of the European existentialists would assist in correcting the problems inherent in these movements; however, May also recognized that the U.S. exists in a rather distinct cultural context than Europe. Thus, if existential-phenomenological psychology were to come to the U.S., it would have to be modified to fit the cultural context better. May developed an existential approach to the study and practice of psychology that was more humanistic in flavor than that of most European existential psychology, closely allying himself with psychologists during his time such as Abraham Maslow and Carl Rogers to develop this new movement in American Psychology. May's approach placed more emphasis on individuality than the already mildly individualistic perspectives of European existentialists to better fit the highly individualistic values of the U.S. He placed more focus on human virtues and strengths than the Europeans and gave greater recognition to the

necessity of some level of isolation and aloneness for the finding of oneself. This set in stone a novel form of existential-phenomenological psychology that would come to be known as the "existential-humanistic" school of existential psychology. This is a sub-movement within the broader existential-phenomenological movement that is fairly unique to the U.S., with only a select few institutions and practitioners dedicating themselves to this school outside of the U.S.[1]

Rollo May's legacy was largely carried on by May's student, colleague, and close friend, Irvin Yalom.[6, 46, 47] Yalom, who had earned his degree as a psychiatrist, began training under May and was greatly inspired to continue the work that May had done to bring the existential movement into the U.S. Upon publishing his Magnum Opus, *Existential Psychotherapy*,[6] Yalom soon became one of the most influential existential-phenomenological psychologists in the United States and continues even to this day to be seen as the key figure in American existential-phenomenological practice. Much like May, Yalom based much of his theory on his experiences as a therapist rather than on systematic research, as these writers were both writing in a time in the U.S. when qualitative and especially phenomenological research methods were widely unpopular. However, their insights are still highly valued by many American psychologists, even outside of the existential-phenomenological tradition.

One of the more contemporary psychologists in the existential-phenomenological tradition in the U.S. is Kirk Schneider. Kirk Schneider, like Yalom, was a student of Rollo May who was highly influenced by May to push for an existential paradigm in American psychology. He is the president of the Existential-Humanistic Institute (EHI), and much of his influence within the movement of existential-phenomenological psychology comes from his involvement in recent major texts in the field, such as the recent *Wiley World Handbook of Existential Therapy*[2] as well as various publications in the *Journal of the Society for Existential Analysis* and other journals such as the *Journal of Humanistic Psychology*, of which he is the former editor.[48] Along with continuing the development of the existential-humanistic discipline founded by May, Schneider is also largely responsible for the development of what is now termed "existential-integrative therapy." This recent addition to the movement of existential-phenomenological psychology involves an integration of other psychological and therapeutic approaches, such as psychoanalysis or cognitive-behavioral therapy, into an approach with prioritized existential foundations. This integration of other paradigms into a fundamentally existential approach to psychology helps to keep existential-phenomenological psychology relevant in the U.S. over the constantly changing times in this culture as well as assisting the approach's acceptance within the American scientific community (which is often even more rigorous than that of Europe).[2]

Schneider also has the potential for yet greater influence over the existential-phenomenological movement in the U.S. now that he is a candidate for the 2020 election of the next American Psychological Association (APA) president. According to Schneider's candidate statement,[49] the U.S. is currently faced with a number of existential crises which must be handled by psychology in order to promote better public mental health across the nation. He believes that this can be achieved with a greater commitment to a "whole-person, integrative orientation to our profession"[49]—a statement that is undoubtedly motivated by his existential-humanistic and existential-integrative approach to psychology. Schneider also lists three primary aims that he would like to fulfill as the APA's new president: greater inclusion of holistic and relational approaches to healthcare, the advocacy of a "psychologist general" office in which an expert in evidence-based integrative practices would collaborate with other agencies to counteract current public mental health crises, and structured dialogue groups which would discuss the highly divisive and polarized state that the U.S. currently faces.[49] Although Schneider uses language in his platform that is more familiar to the rest of the American psychological community (as opposed to the somewhat esoteric language used by many existential phenomenologists,) the existential and phenomenological foundations for his platform are undeniable, and if Schneider is successful in becoming elected as the next president for the APA, then this will prove to be a significant accomplishment in the development of this movement within the U.S.

Another significant development of existential and phenomenological approaches to psychology was the foundation of the *Simon Silverman Phenomenology Center* (SSPC) at Duquesne University by Amedeo Giorgi, along with John Sallis. Giorgi and Sallis founded the *SSPC* to be a "live center" for research and new developments in phenomenology.[50] While most of the leaders in existential-phenomenological psychology in America mentioned above were more concerned with developing and applying an existentially and phenomenologically oriented psychotherapy, Giorgi and his colleagues at Duquesne University have been more concerned with developing a research method in the phenomenological tradition that could be used in this movement.[51-55] While May, Yalom, and Schneider seem to be disenchanted with the research paradigms most prevalent in the U.S., and thus choose to base their theories on practical experience in therapy rather than systematic research (Schneider being an occasional exception), the psychologists at the *SSPC* sought to develop a new research paradigm in the U.S. which would rather prioritize phenomenological methodologies, and thus be more useful in the field of phenomenological psychology. They were eventually successful in doing so, putting together the *Journal of Phenomenological Psychology*—the first peer-reviewed journal dedicated to research in psychology from the phenomenological tradition. This was a breakthrough event in the history of existential-phenomenological psychology, as the movement now had a way to publish original research in its own tradition that would be respected in the scientific community. One should note that the *SSPC* does not necessarily constrict itself purely to *existential* phenomenology, but rather

devotes itself to research and developments in all areas of phenomenology. However, as mentioned in the first section of this article, since Heidegger's fusion of phenomenological thought with existential thought, existential phenomenology has become one of the most prominent forms of phenomenological study in all fields. Because of this, the development of such a center as the *SSPC* inherently assists in bringing existential phenomenology, and especially existential-phenomenological psychology, into the U.S.

Eventually, other schools in the U.S. began developing their own programs in phenomenological psychology, often as a result of Duquesne University graduates going on to become professors at these schools. One of the most notable examples of this is the *University of West Georgia*, with Duquesne University graduates Chris Aanstoos (retired), Eric Dodson, Alan Pope, and Nisha Gupta, which is one of few American schools other than Duquesne University with a doctoral program in phenomenological psychology.[56] Another notable example is *Seattle University*, with Duquesne University graduate Steen Halling, which offers an MA in psychology with a particular focus on phenomenological psychology (including existential-phenomenological psychology).[57] The *University of Dallas*, with Duquesne University graduates Scott D. Churchill, Gilbert Garza, and Stephanie Swales, also offers multiple Master's programs in phenomenological psychology.[58] *Point Park University*, with Duquesne University graduates Brent Robbins, Robert McInerney, Kurt Kumler, and Autumn Redcross, also offers a Psy.D. in psychology with a phenomenological focus.[59] Finally, *Fordham University* also has the Duquesne University graduate Frederick Wertz, who specializes in qualitative research methods and phenomenological and existential psychology at this university.[60, J] One should also note the influence of Saybrook University on the existential-phenomenological movement in Psychiatry, which, despite not having many direct connections to Duquesne University or any of the other universities mentioned above, offers an M.A. and a Ph.D. degree in Psychology with humanistic, existential, and transpersonal specializations as well as a Ph.D. in clinical psychology that draws upon similar humanistic, existential, and transpersonal influences.[61] Saybrook University was, in fact, founded by the Association for Humanistic Psychology (AHP)[K]—an association dedicated to further developments of "Third Force" psychologies (humanistic, existential, and transpersonal psychology) in the U.S.[2] Saybrook University is unique in this regard, for it is one of few institutions in the U.S. founded *specifically* for specialization in the humanistic and related movements in psychology, making it a noteworthy contributor to the movement of existential-phenomenological psychology in the U.S.

Despite these successes of existential-phenomenological psychology in the U.S., the movement has still faced, and continues to face, many threats[L] to its development in this country. As mentioned above, the movement tends to be very dissonant with the traditional scientific standards of American psychology, which much prefers quantitative and experimental methods to studying psychology than is usually offered by the existential-phenomenological approach. One can see this highly positivistic focus in existential-phenomenological psychology's first great competitor in the U.S.: behaviorism. Because of behaviorism's incredibly positivistic mandates of observing human behavior specifically, and ignoring such phenomena as consciousness, emotions, cognitions, or—seemingly the worst of all to early behaviorists—free will, seeing all of these as not being scientifically measurable,[62-64] behaviorism was set in stark opposition to existential phenomenology. This is due to existential-phenomenological psychology's dedication to studying the unity between objective and subjective phenomena, always attempting to connect observable behaviors with some deeper phenomenon that is only understandable through the acknowledgement of consciousness. The popularity of this radical approach to behaviorism in the U.S. during the time when existential-phenomenological psychology was first introduced to the country immediately set the movement up against a powerful threat to its existence.[29, 44, 45] Of course, this approach to behaviorism began falling out of favor quickly, as people began to recognize the necessity of acknowledging phenomena less tangible than behavior—even modern behaviorism has begun to acknowledge that they must assume some form of consciousness to exist in psychology (see, for instance, source **65**). However, the challenge was far from over.

Even after behaviorism began to pose less of a threat to existential-phenomenological psychology, the emphasis on collecting quantitative data over more qualitative procedures in research has never ended. This continues to be the main threat to existential-phenomenological psychology's existence, as its more qualitative methods to studying psychology are frequently looked down upon by respected leaders in American academic psychology. One particularly prominent threat right now is the development of "experimental existential psychology," which studies the same topics as existential-phenomenological psychology except with more experimental methodologies.[10] Because this movement applies methodologies that are more accepted in the U.S.'s scientific community to the same topics that existential phenomenology studies, it can easily replace existential phenomenology as the leading source of information on these topics. Indeed, this movement seems already to be gaining more attention than the original tradition of existential-phenomenological psychology.

It should be clarified, of course, that existential-phenomenological psychology need not necessarily invalidate the more accepted scientific traditions in the U.S. altogether. Though some leaders in the movement may be distrustful of experimental and quantitative methods,[M] there are those that also believe in setting up a dialogue between these methodologies and the phenomenological methodologies to which they ascribe.[N] It may seem, indeed, that it would serve the movement best to take this

latter position, as this may avoid a fundamental threat to the U.S.'s cultural values, which would, of course, ensure the termination of existential-phenomenological psychology's transition into the nation. This approach would allow for a harmonious relationship between each tradition, which would ease the competition that currently exists between existential phenomenology and its more successful "opponents." In particular, experimental existential psychology has the potential to become more of an ally to existential-phenomenological psychology than a competitor if academics from both traditions can use their differences to complement each other and expand upon each other's theories. There have also been many developments in the U.S. recently that have worked to the favor of existential-phenomenological psychology's more qualitative focus in research. For instance, Division 5 of the APA added a new subdivision known as the *Society for Qualitative Inquiry in Psychology* (SQIP) in the year 2011 and changed its name from "Evaluation, Measurement, and Statistics" to "Quantitative and Qualitative Methods" in 2014 in order to represent a more equitable recognition of quantitative and qualitative methods as equally valuable research approaches.[66] Recent challenges to the traditional quantitative-qualitative dichotomy in research have also proven favorable for existential-phenomenological psychology. For instance, the possibility of mixed methods research is promising in its potential for synthesizing phenomenological psychology with some of the more respected traditions in psychology. Some recent figures in existential-phenomenological psychology have begun to recognize the value that methodological pluralism and mixed methods may have for the movement, calling into question psychology's history of dichotomizing qualitative research methods from quantitative ones.[67, 68] The scene for qualitative research has certainly become more favorable in the U.S.; however, it continues to exist as more of an alternative to quantitative methods than as a leading tradition in itself,[69] and regardless of how most existential-phenomenological psychologists approach the situation, the hostile environment that it must confront in the U.S. is sure to be an issue in its development for many years to come.

THE FUTURE OF EXISTENTIAL-PHENOMENOLOGICAL PSYCHOLOGY

Despite having enjoyed many successes, existential-phenomenological psychology retains many tasks to complete before it can become a truly respected approach to psychology around the world. Emmy van Deurzen[70] emphasizes the necessity for existential-phenomenological psychologists to remain flexible in the upcoming thirty years and to be willing to adapt to the changing cultural and historical context of the world. If the movement is not open to adapting itself to best suit the needs of those it serves, then it is sure to fail its goal of persisting and expanding. However, if it also allows itself to change its fundamental principles in the name of becoming more accepted, then it will no longer be the same movement. Thus, those who are deeply involved in the movement must reflect very deeply on what should and should not be adapted in the paradigm to fit the social context in which it continues to develop—a task that will certainly not be easy. Indeed, one could say that existential-phenomenological psychology must subject itself to its own critical processes and must reflect upon its own existence as a collective intellectual movement to understand its relation to the world in which it is developing.

This challenge, a worldwide concern for existential-phenomenological psychology, seems to be especially relevant in the United States. Because of existential-phenomenological psychology's unique position in the U.S., as a movement that has on one hand been somewhat accepted into the social climate and on the other hand is still new and suspicious to many, those who seek to further the movement's development must choose their actions very carefully. They must ensure that no other authorities manage to take away the movement's foundations and force it to conform to any criteria to which it does not belong. However, they must also be careful not to take away the foundations of traditional American psychology either. They must critique the shortcomings of other approaches to psychology in America, but they must not allow this to become an argument for the dominance of this movement over these other movements. They must also be aware of the vast diversity of people peculiar to the U.S., for the U.S.'s heterogeneous population calls for approaches that can constantly adapt to best fit each person with whom it works.

Despite the uncertainty of the movement's future, there is still much potential to further the development of existential-phenomenological psychology in the U.S. Existential-phenomenological psychology could prove helpful, over time, with many of the U.S.'s contemporary issues. For instance, it could help American citizens to find their place in a social environment that is ever-changing and constantly readapting to new situations. It can help these citizens, who live in an increasingly individualistic cultural context, to understand and make peace with the isolation that is inherent in such a social phenomenon. It can also help some of the many people in the U.S. with multicultural backgrounds to make sense out of who they are and what their differing and occasionally conflicting identities mean for them. Most importantly, however, may be existential-phenomenological psychology's capabilities in confronting the ongoing COVID-19 pandemic, which is bound to raise various existential issues for people around the world and particularly in the U.S.[0] With much hard work and perseverance, and perhaps some good fortune, the existential-phenomenological movement in psychology will come to thrive in the U.S.

CONCLUSION

The existential-phenomenological movement in psychology has the potential for much success and contribution in American psychology but has not yet reached its highest potential in this region. This paper, in providing a comprehensive account of the history and major figures of this lesser-known movement, is offered to help the movement become more familiar to American

social scientists and laypeople alike and to help this audience to know where to start looking to gain an understanding of this perspective. An argument for adopting more existential-phenomenological principles is also provided, including a discussion of the relevant issues to modern American society which existential-phenomenological psychology can tackle and a review of how the movement's influence can be sustained and increased. In time, if this emerging movement becomes familiar enough to influential American psychologists, its contributions can be realized to their highest benefit to American society.

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FOOTNOTES

A. Notably, Sigmund Freud also attended these lectures by Brentano.[2] This fact is highlighted by various scholars to show the differences between Freud's interpretation of Brentano's concept of intentionality and Husserl's interpretation. This divergence seems to reflect a complex relationship between phenomenology and psychoanalysis that would develop soon after these two figures attended these lectures.

B. See also Heidegger's works *Discourse on Thinking*[71] and *Introduction to Metaphysics*.[72]

C. Or, in Jaspers' own terminology, "Philosophy of Existence", as he proposed to call it in his 1938 book of the same name (translated into English in 1971).[28]

D. NOTE: In this article the term "anthropology" should not be confused with its general usage in reference to the study of "cultural anthropology", which studies the differences between cultural and ethnic groups across space and time. In the sense used here, "anthropology" simply refers to a study of what it means to be human.

E. Some of these thinkers' works can be found in source **36**.

F. "Daseinsanalyse" in the original language of German. This term has been given many translations, such as "Daseinsanalysis" (as seen above), existential analysis,[36] and "Dasein-analysis".[73] Because of the confusion these differing translations have created, I have decided simply to use the most common translation, despite some flaws it may have.[73]

G. A few of Binswanger's works can be found in source **36**.

H. See his works in source **36**.

I. This school has had to be renamed many times due to each name's misleading nature, and no perfect name for it truly exists. It was first named the "London School of Existential Psychotherapy," although its founders had to change this name because it is practiced in areas outside of London. It was then changed to the "British School of Existential Psychotherapy," but major proponents had to change it from this name since it is practiced in countries outside of Great Britain as well. For a brief period, some wanted to call it the "European School of Existential Psychotherapy," though this trend ended quickly due to its already rapid growth to regions outside of Europe. This name also fell out of favor because the number of existential therapies based in Europe are so numerous that no single one can be fairly called "the" European School of Existential Psychotherapy. Most recently, experts have been settling on calling it the "existential-phenomenological" school of psychotherapy, although this was very tentative, as all primarily existentially oriented schools of psychotherapy are existential-phenomenological therapy.[2] In this paper, I use the name of "the British School of Existential Psychotherapy", as I felt this to be the most fair name and also felt that it would eliminate the confusion that would inherently be present were I to use the name "existential-phenomenological therapy." One should remember that I had stated that all of the existential therapeutic paradigms discussed in this article would be a part of the existential-phenomenological movement.

J. This list is by no means exhaustive of all of the schools and professionals influenced by Duquesne University. I am sure that there are other schools in the U.S. with Duquesne University graduates as well as other Duquesne University graduates at the schools listed whom I did not mention. I was only able to list all of the schools that I could find and all of the faculty members there who were confirmed to be Duquesne University graduates either on the university websites or by common knowledge. Also, one should note that Duquesne University graduates are not the only American psychologists who practice phenomenology. There are plenty of practitioners of phenomenological psychology at the universities listed as well as others who did not study at Duquesne University at all. The purpose of my mentioning the names of these psychologists is to show the specific influence of Duquesne University over phenomenological psychology in the U.S.

K. This school was even originally named the "Humanistic Psychology Institute" to reflect the highly humanistic-based thinking of its founders. It was later re-named "Saybrook University", after a famous conference named the "Old Saybrook Conference" in which various leading figures in the "Third Force" movement in American psychology, including leaders of the existential-humanistic movement, convened to discuss the philosophy and direction which the AHP should take.[2]

L. Some readers may find the word "threat" to be a bit strong, but by 'threat" I do not necessarily mean a force actively working to suppress existential-phenomenological psychology. I simply mean any force that either actively attempts such an action or simply has this effect passively. Some of the "threats" to existential-phenomenological psychology discussed may have actively attempted to discount the movement, but many of them had no such intention and simply threatened the movement because of their greater success in the U.S.

M. Irvin Yalom, for instance, tended to view most experimental studies with skepticism.

N. Phenomenologists in the tradition of Interpretative Phenomenological Analysis (IPA), for instance, prefer to view their method as a complement to experimental methods rather than a replacement of them.[74] Also, as mentioned later in the article, figures such as Joël Vos, Mick Cooper, Edgar Correia, and Meghan Craig[67] as well as Mick Cooper and John McLeod[68] have begun promoting a pluralistic approach to research and counselling methodology in recent years, arguing that a balanced presence of all research methods is the most effective way to contribute to the field of psychology.

O. One should take note of the fact that at the time this paper was written, the U.S. had the highest number of reported COVID-19 cases out of every country in the world.[75] This may no longer be true by the time this article is published, but regardless of whether it is or not, the fact that the U.S. was, at one point, the country with the largest impact of COVID-19 is certain to make existential concerns more relevant to people in this nation for many years to come.

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PRESS SUMMARY

This paper reviews the "existential-phenomenological" approach to psychology in terms of its basic principles and the history of its development. It starts by explaining the theory and practice of existential-phenomenological psychology and then gives a survey of many of the most influential figures in the movement's history. A particular focus is placed on existential-phenomenological psychology's success in the U.S., with a discussion of how to further bring the movement into American society presented as well as an observation of the uncertainty surrounding the movement's future, with the potential both for failure and for further success being possible.

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