# ADVANCED SCIENCE RESEARCH

# A GUIDE FOR **STUDENTS**


*Photo credit: CGPS*

Inspired by the pioneering work of Robert Pavlica, PhD

*"If the teacher knows more about the topic than the student does, then the student doesn't know enough"* – Dr. Pavlica

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Rev. April 2021

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# A Message for Interested Students

We're glad that you're showing interest in ASR! Don't worry if you haven't been doing "sciency stuff" since kindergarten. Don't worry if you aren't known as a "science person." Don't worry if you're not sure whether you "have it in you" to become a student researcher. If you are excited by the prospect of discovering a tiny sliver of the universe that nobody had ever known before or making something nobody else had, no matter how much time and toil it will take you – we want you. If you have the heart to keep that end goal before your eyes and be brutally honest in the process, and the guts to do an incredible amount of high-level work to get where you want to get – we want you.

# The Philosophy

The goal of the course is to immerse you into college-level STEM research. It is aimed at students who wish to pursue excellence and progress into advanced areas of original research. Emphasis is on both laboratory and bibliographic research. The course will develop and foster your commitment to long-term focused research that demonstrates initiative, perseverance, and creativity.


*Photo credit: CGPS*

# An Overview

This program affords you the opportunity to participate in authentic, advanced scientific research and scholarship as part of your high school experience. It furthers excellence in performance and achievement while drawing from and developing scientific capabilities. Students taking the course accomplish the following:

- They choose and explore a topic of interest (see Appendix on page 11). It may come from any area of basic or applied science, mathematics, medicine, or engineering. They develop researching skills using professional databases and other research tools.

- They find and study numerous journal articles, using textbooks and other articles to fill in their gaps in understanding so that they are able to explain every detail of each article and its significance.

- Once they have read a critical mass of literature on their narrowly-defined topic, they use it to write a review article that outlines the background of the topic, the cutting edge of our understanding of it, and the outstanding problems.

- Students contact a scientist who has completed research in the field they wish to study and ask the scientist to serve as a mentor to assist them in carrying out a research project in their area of interest. You will learn how to do this yourself.

- Students then engage in an original piece of research under the supervision of their external mentor and their ASR teacher. This may be the student's own project, or the student may assist the mentor in some meaningful manner. If the student works on the mentor's research, it is the student's responsibility to acquire sufficient knowledge and skills to become a genuine asset to their mentor. Many students eventually know more about their highly focused topic than their teachers.

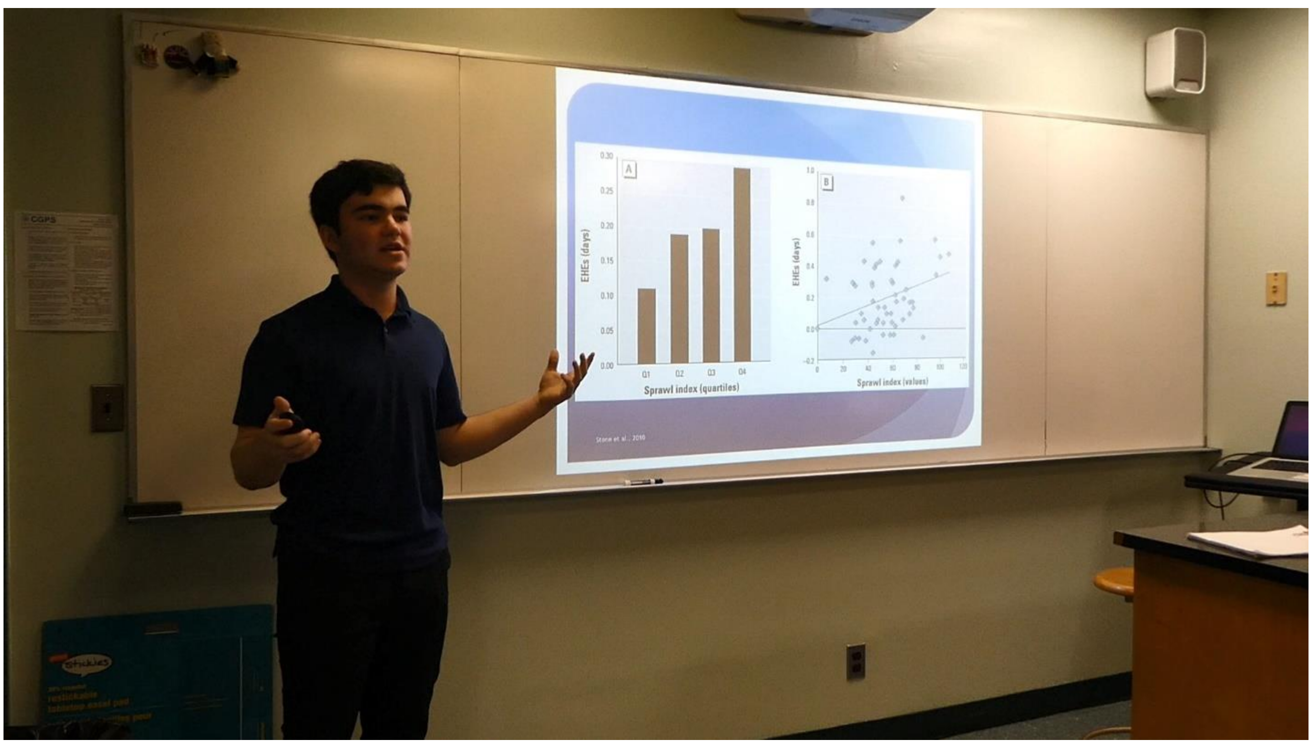
- Students will be taught fundamental inferential statistics, which they will competently use for understanding the research they read and for doing their own research, including tests such as the t-test, ANOVA, and Pearson's r. Most students complete their own data analyses or actively assist the mentor with theirs.

# The Three-Year Syllabus

## APPLYING TO THE PROGRAM

You can apply to ASR in the spring of 9th grade. The application consists of two parts: An essay showcasing your extracurricular involvement with science or your scientific approach to the world, and a three-minute presentation of a science article to us, followed by a brief Q&A. Recommendations from your science and mathematics teachers and your grades in science and mathematics are considered, but we accept students from a wide range of ability levels as long as the student demonstrates grit, determination, and strong self-responsibility. Once accepted, you will choose a tentative STEM area of interest.

Then, over the summer, you will read and summarize 12 science articles on your topic, from popular periodicals and books. This will help you to explore new areas and begin developing questions that appeal to you, and which may later turn into potential research projects!

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## SOPHOMORE YEAR

During this year, you will continue to narrow the focus of your topic. You will master researching skills using additional lay articles and textbooks, as well as online research databases such as ScienceDirect and Google Scholar. The class meets every day and every student has an individual meeting with the teacher approximately every two to three weeks to monitor progress and discuss the next steps. When you are ready, you will select approximately between 5 and 15 journal articles in your field of inquiry. You will use these articles to write a comprehensive 20 to 40 page Review Article on your topic, properly referenced and cited. The article is written to be comprehensible both to a lay person as well as to a researcher, and this will push your understanding of the subject to a deeper level. The draft goes through as many revisions as is necessary until you are writing at a higher scientific level than you thought possible.

Throughout the year, you will read approximately five journal articles per quarter, in addition to developing presentation skills, statistics knowledge, and an understanding of APA formatting and the formatting most commonly used in your field.

Each sophomore is also required to make a presentation about the current state of research in their field, based on their Review Article. The presentatio includes an overview of the importance of the topic, an explanation of relevant fundamental concepts, an overview of several key journal articles, and avenues for further research on the topic

Only after completing this assignment and the Review Article to the satisfaction of the research teacher will you be permitted to contact the authors of the journal articles that you have thoroughly read. It is this contact that often develops into a student-mentor relationship. It is astonishing how readily many professors will consider mentoring a student who has read and understood their publications and shows genuine interest in conducting research in the same field.
Once you have found a mentor, you can start working together remotely and then in person, often in a laboratory, and possibly continuing into the summer.

## JUNIOR YEAR

You and your mentor will work together to develop a vision of what the collaborative research will be. As during the rest of the program, you will be expected to give back as much as you get; you will become an asset to your mentor. Contact with the mentor is maintained every week or two by phone calls, video calls, and/or email. You will actively engage in, or prepare for, the type of research necessary for your field, whether it is field work, bench research, or coding. Depending on the type of work at hand, you and your mentor may choose to work together remotely. The hypothesis will be revised and redefined as needed, based upon literature readings and new experimental directions. Journal readings will proceed at the rate of about five per quarter, or as suggested by the mentor. Many mentors supply or suggest advanced textbooks to the student, and it is the student's responsibility to learn the material.

You will continue to meet with your school ASR teacher individually approximately every two to three weeks to discuss the ongoing research, attend lecture classes on research topics, and learn lab skills, programming, etc., as needed. During this year, you will give public presentations of the progress of your research findings to the teacher, the class, and the school community, following a format similar to that of many research staff meetings. Juniors who plan to work with human subjects follow the approval guidelines of an Institutional Review Board to minimize risk. If needed, the student receives HIPAA and/or IACUC training to handle private subject data or to work with animals.

If you complete a research project by around the end of the first quarter of your junior year, you will write a research paper and submit it to several science research competitions, such as the Junior Science and Humanities Symposium and the International Science and Engineering Fair, as well as non-competitive venues such as academic conferences. This will provide you an excellent opportunity to hone your writing and presenting skills. Meanwhile, you will either continue your work on this project or start a new research project that you will complete by the beginning of your senior year.

## JUNIOR-SENIOR SUMMER

**You must keep this summer open for your ASR work.** This summer (as well as junior school year and, possibly, the previous summer – every student's path is unique) is dedicated to performing real experiments, collecting data, and analyzing your results. Many students spend part or all of this summer working directly with their mentor, although some conduct their research independently while maintaining regular communications with their mentor and ASR teacher.

By the first day of the senior year, you must complete all part of your research project and write a full draft of your research paper. You will receive instruction on how to write the paper in the last few weeks of the previous semester. You will also be required to learn and follow the guidelines issued by the Society for Science for advanced high school science research, including guidelines for animal care and hazardous materials handling.

*Photo credit: CGPS*

## SENIOR YEAR

As a senior, you will continue to meet daily with the class and individually with the teacher at least every two to three weeks to ensure that all goals and objectives are reached. You will revise your research paper and begin making a formal presentation of your research. Once your paper is approved by your teacher and your mentor, you will submit it to the Regeneron Science Talent Search (STS) and the International Science and Engineering Fair (ISEF), two of the most prestigious high school science competitions in the world. You will also submit it to the Junior Science and Humanities Symposium.

Although participating in these research competitions is a requirement, it is not the goal of the program. The goals of the program are for you to learn valuable skills, do solid research, and share your work with the world. The competitions provide venues for you to do so, concrete goals to work toward, a nationally recognized set of standards to meet, and the opportunity for experts in the field to evaluate your work.

You will also be encouraged to find non-competitive venues to present at. The presentations that students cherish the most often involve the challenge of presenting to your mentor's research group or at a professional conference. Each student also presents their work to the school community at our annual Symposium in May.

*Credit: Regeneron STS*

*Credit: Regeneron ISEF*

*Credit: JSHS*

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# COME JOIN US!!


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## Contact Information

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# APPENDIX

## ACCEPTABLE AREAS OF STUDY

*Source: Regeneron Science Talent Search*

**ANIMAL SCIENCES:** Study of animals – ornithology, ichthyology, herpetology, entomology, animal ecology, paleontology, cellular physiology, circadian rhythms, animal husbandry, cytology, histology, animal physiology, invertebrate neurophysiology, studies of invertebrates, etc.

**BEHAVIORAL AND SOCIAL SCIENCES:** Human and animal behavior, social and community relationships – psychology, sociology, anthropology, archaeology, ethology, ethnology, linguistics, learning, perception, urban problems, public opinion surveys, educational testing, etc.

**BIOCHEMISTRY:** Chemistry of life processes – mechanisms of molecular biology and genetics, enzymes, photosynthesis, blood chemistry, protein chemistry, food chemistry, hormones, etc. Studies involve understanding life and cellular processes specifically at the molecular level.

**BIOENGINEERING:** Engineering principles applied to biology or medicine, such as bodily aids or replacements, medical/diagnostic devices, and drugs or other therapies using engineering to address a biological problem.

**CELLULAR AND MOLECULAR BIOLOGY:** Wide ranging field that studies cellular structure, function, biomolecule trafficking, signal transduction, genetic information flow, and cellular replication.

**CHEMISTRY**: Study of nature and composition of matter and laws governing it – physical chemistry, organic chemistry (other than biochemistry), inorganic chemistry, plastics, fuels, pesticides, metallurgy, soil chemistry, etc.

**COMPUTATIONAL BIOLOGY AND BIOINFORMATICS:** Studies that primarily focus on the discipline and techniques of computer science and mathematics as they relate to biological systems. This includes the development and application of data-analytical and theoretical methods, mathematical modeling and computational simulation techniques to the study of biological, behavioral, and social systems.

**COMPUTER SCIENCE:** Study and development of computer hardware, software engineering, internet networking and communications, graphics (including human interface), simulations/virtual reality or computational science (including data structures, encryption, coding and information theory), etc.

**EARTH AND PLANETARY SCIENCE:** Geology, mineralogy, physiography, cryosphere, ocean sciences, geomagnetism, hydrology, meteorology, climatology, speleology, seismology, tectonics, volcanology, planetary science, etc.

**ENGINEERING:** Technology; projects that directly apply scientific principles to manufacturing and practical uses – civil, mechanical, aeronautical, chemical, and electrical engineering; electronic, sound, automotive, marine, heating and refrigeration, transportation, environmental engineering, etc.

**ENVIRONMENTAL SCIENCE:** Study of ecology, sustainability, climate, and human impacts, including pollution from air, water or land sources and their control or remediation, etc.

**GENOMICS:** DNA microarray and deep sequencing studies; phylogenetic analysis of DNA or other biomolecules; analysis of human or other genomes, molecular evolution, etc.

**MATERIALS SCIENCE:** The structure, engineering properties, processing, and innovative uses of metals/alloys, polymers, ceramics, glasses, electronic materials, biomedical materials, composites, and other innovative materials at scales ranging from the atomic to the macroscopic, etc.

**MATHEMATICS:** Development of formal logical systems or various numerical and algebraic computations, and the application of these principles – calculus, geometry, abstract algebra, number theory, statistics, probability, etc.

**MEDICINE AND HEALTH:** Study of diseases and health of humans and animals – pharmacology, physiology, pathology, ophthalmology, oncology, cardiology, nephrology, endocrinology, pediatrics, dermatology, allergies, speech and hearing, nutrition, dentistry, etc.

**PHYSICS:** Theories, principles, and laws governing energy and the effect of energy on matter – solid state, optics, acoustics, particle, nuclear, atomic, superconductivity, thermodynamics, magnetism, quantum mechanics, biophysics, etc.

**PLANT SCIENCES:** Study of plant life – agriculture, agronomy, horticulture, forestry, plant taxonomy, plant physiology, plant pathology, plant genetics, hydroponics, algae, etc.

**SPACE SCIENCE:** Study of celestial bodies, their positions, motions, nature and evolution – astronomy