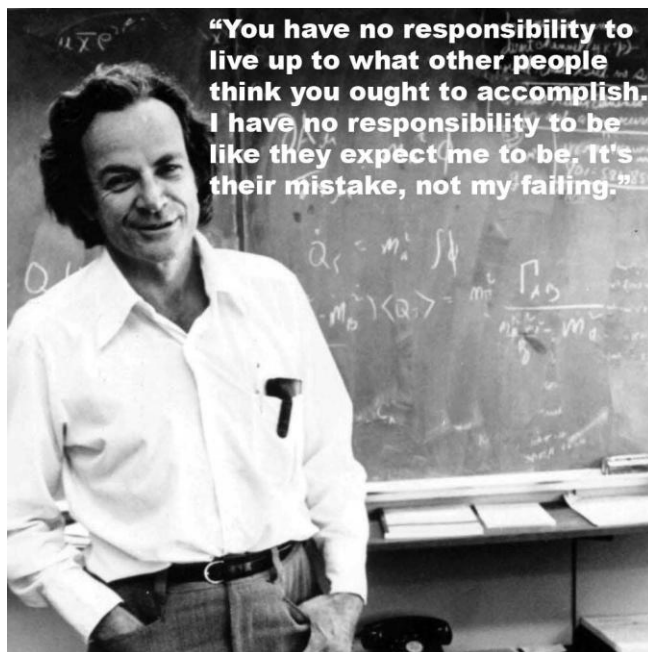


Article 1: What is nanoscience?

Way back in 1959, a physicist named Richard Feynman shared his vision of what very small things would look like and how they would behave. In a speech at the California Institute of Technology titled “There’s Plenty of Room at the Bottom,” Feynman gave the first hint about what we now know as “**nanoscience**”[1]:

“The principles of physics, as far as I can see, do not speak against the possibility of maneuvering things **atom** by atom.”



More generally, nanoscience is the study of the behavior of objects at a very small scale, roughly 1 to 100 nanometers. A nanometer is one billionth of a meter, or the length of 10 hydrogen atoms lined up. Nanosized structures include the smallest of human-made devices and the largest **molecules** of living systems.

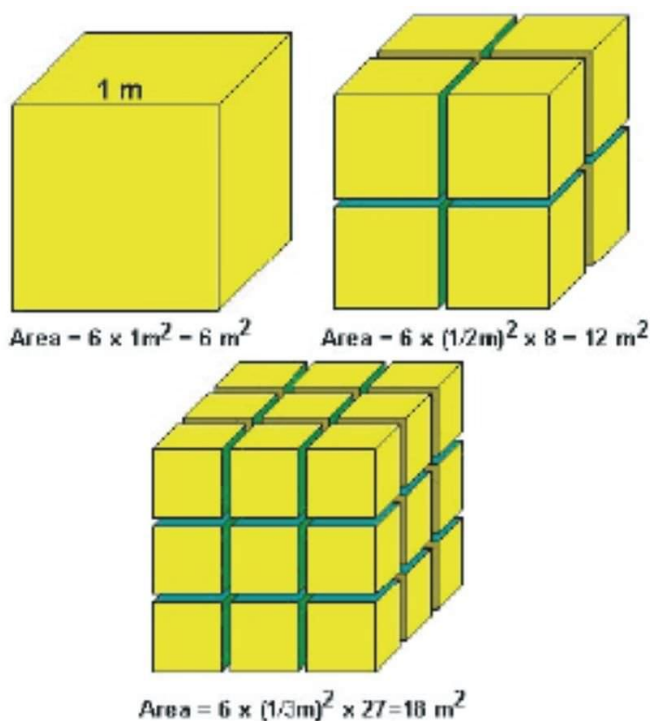
What is the Big Deal About Nanoscience?

You might ask, “What is the big deal with nanoscience? Isn’t it just a bunch of really small things?” It is, in fact, a bunch of small things. But it is a whole lot more. What makes the science at the nanoscale special is that at such a small scale, while all physical laws affect the behavior of matter, different laws dominate over those that we experience in our everyday lives. For example, the **element** gold (Au) as we are used to seeing it has a nice yellowish-brown color to it—the color we know as “gold.” However, if you had only 100 gold atoms arranged in a cube, this block of gold would look very different—its color would be much more red. Color is just one property (optical) that is different at the nanoscale. Other properties, such as flexibility/strength (mechanical) and **conductivity** (electrical) are often very different at the nanoscale as well.

Article 2: Surface Area is Big!

The smaller something is, the larger its surface area is compared to its volume. This high surface-to-volume ratio is a very important characteristic of **nanoparticles**. For example, imagine that you have a big block of ice with one-meter sides (see Figure 1). This block has a surface area of 6 m^2 (each side is 1 m^2 , 6 sides to a cube). In this case the surface area to volume ratio is 6. Suppose that ice cube is cut into 8 separate cubes, pieces that are one-half of a meter per side. The surface area of each piece of ice would be 1.5 m^2 ($0.5 \text{ m} \times 0.5 \text{ m} \times 6$ sides). So the total surface area of all the pieces would be 12 m^2 . However the total volume of ice would stay the same: We haven't added or removed any ice. So in this case, the surface area to volume ratio is $12/1$ or 12 - twice the surface area to volume ratio of the block before it was cut.

If you cut the ice into 27 pieces, the surface area increases to 18 m^2 , and the surface to volume ratio is $18/2$ or three times that of the uncut block. If you keep going, and cut the ice into 1000 small pieces, the surface area to volume ratio is $60/1$ or ten times that of the uncut block! Imagine how big the surface area to volume ratio would be for something that is as small as a bunch of **nanoscale** particles.



[Figure 1]

Total surface area increases as you cut the block into smaller pieces, but the total volume stays constant [2].

The vastly increased ratio of surface area to volume makes interactions between the surfaces of particles very important. If something has more surface area, there are more places for other chemicals to bind or react with it. For example, fine powders offer greater reaction speed because of the increased surface area. Think about how much faster you can cool a glass of water if you put crushed ice in it rather than ice cubes. Nanoscale particles maximize surface area, and therefore maximize possible **reactivity!**

Why is Large Surface Area Important?

The large surface area to volume ratio of nanoparticles opens many possibilities for creating new materials and facilitating chemical processes. In conventional materials, most of the atoms are not at a surface; they form the bulk of the material. In **nanomaterials**, this bulk does not exist. Indeed, **nanotechnology** is often concerned with single layers of atoms on surfaces. Materials with this property are unique. For example, they can serve as very potent **catalysts** or be applied in thin films to serve as thermal barriers or to improve wear resistance of materials.

Source :nanosense. *Lesson 1: Introduction to Nanoscience Student Materials.*

https://nanosense.sri.com/activities/sizematters/introduction/SM_Lesson1Student.pdf.

Article 3: Careers in Nanotechnology

As nanoscale science and engineering come to have an increasing impact on many aspects of our daily lives, the opportunities for careers are expanding rapidly. A major challenge is the education and training of a new generation of skilled workers. Could you be one of them? Do you want a career in a new and exciting field which is predicted to impact every facet of our lives?

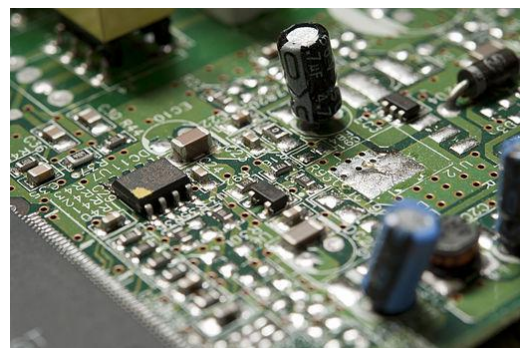
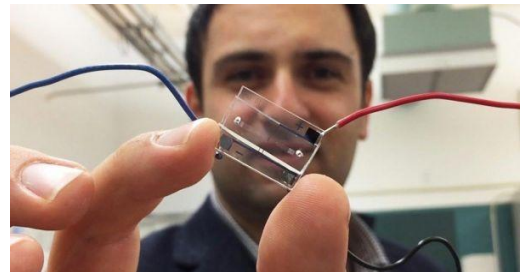
In areas as diverse as designing medical diagnostic devices to building better batteries, from creating cosmetics to enhancing energy efficient windows, from auto and plane manufacturing to researching the nature of matter itself, knowledge of nanoscale science and engineering will be increasingly important during upcoming years and decades.



Where are the career areas?

Current applications of nanoscale science and engineering, and thus career opportunities, exist in areas such as:

- Electronics/semiconductor industry
- Materials science including textiles, polymers, packaging, among others
- Auto and aerospace industries
- Sporting goods
- Biotechnology
- Computing
- Medical fields and pharmaceuticals
- Environmental monitoring, control, and remediation
- Food science including quality control & packaging
- Agriculture
- Forensics
- Geosciences
- Microscopy
- University and federal lab research



- Military and national security
- Energy capture and storage
- And many more areas

What Education is Needed and in which Fields?

Nanoscale phenomena underlie many of the properties and interactions of matter, and thus the sciences of physics, chemistry, and biology. However, nanoscale science is an interdisciplinary field – one where science and engineering intersect. Studying science or engineering and paying attention to the developments in nanoscience that advance these fields can provide you with a solid foundation for any broad range of careers.

What Type of Education is Needed for a Career in Nanotechnology?

Not everyone working in nanotechnology will require a doctorate degree in science or engineering. A skilled workforce trained at a variety of levels is needed to meet the projected workforce challenge. Education levels include:

- Technical program - high school degree plus additional certificate or vocational training
- Associate's degree - 2 years of college
- Bachelor's degree - 4 years of college
- Master's degree - about 6 years of college total
- Doctorate - about 9 years of college total



You might want to check out these sites for further information on education programs:

- National Nanotechnology Initiative's Schools and Training Programs:
[Associate Degrees, Certificates, and Job Opportunities](#)
[College, Graduate School, and Postdoctoral Opportunities](#)
- [Nanotechnology Applications and Career Knowledge Network](#) has a section for students to find a two-year nanotech degree program:

What are the Expected Salaries?

- Two Year Associate's - \$35,000 - \$52,000
- Four Year Bachelor's - \$40,000 - \$65,000
- Six Year Master's - \$60,000 - \$80,000
- Eight Year Doctorate - \$75,000 - \$150,000

U.S. salaries for nanotechnology engineering range from \$52,000 to \$150,000 with the average \$95,000 according to [Recruiter.com](#). This site lets you explore the average salaries by state. [SimplyHired](#) shows the range as \$36,000 to \$120,000 with the average at \$66,000. Some additional sites to explore:

[Click here](#) to access and download NNCI's brochure on Careers in Nanotechnology for high school students.

- <http://www.nano.gov/education-training>
- <http://www.tinytechjobs.com/>
- <http://www.nanowerk.com/nanocareer/homepage.php>
- <https://www.ziprecruiter.com/Salaries/Nanotechnology-Salary>
- <https://foresight.org/category/nanojobs/>

The National Nanotechnology Initiative has the [US Nano and Emerging Technologies Student Network](#). The network consists of undergraduate student-run clubs at universities and colleges across the country that is building an interdisciplinary community of students with a focus on future technologies.

ACS Citation: *Careers in Nanotechnology* | NNCI. nnci.net. <https://nnci.net/careers-nanotechnology>.

Article 4: Nanotechnologist Job Description

Education and Training Requirements

High School

You can prepare for a career as a nanotechnologist by taking mathematics (geometry, trigonometry, and calculus) and science (biology, chemistry, and physics) classes and by joining science and math clubs. Take computer science courses to learn how to use databases, word-processing programs, and computer-aided design software. Shop classes will help you to develop your technical skills and hand-eye coordination, which you'll need to be successful when you work in a laboratory. English and speech classes are important because nanotechnologists frequently write reports and communicate their findings to colleagues.

Postsecondary Education

A minimum of a bachelor's degree in nanotechnology, nanoscience, laboratory science, engineering technology, materials science, biotechnology, chemistry, biology, or a related field is required to become a nanotechnologist. Some employers may require just an associate's and previous experience in the field, but the majority of jobs require a bachelor's degree. More than 25 community colleges offer associate degrees and certificates in nanotechnology-related fields. Many more colleges offer bachelor and advanced degrees in nanotechnology. A typical nanotechnology curriculum includes a combination of classroom and hands-on laboratory experience. Typical classes in nanotechnology programs include:

- introduction to nanotechnology
- nanotechnology safety
- general chemistry
- chemistry laboratory
- statistical process control
- nanotechnology materials
- general physics
- general physics laboratory
- nanotechniques and instrumentation
- molecular biology techniques

The following Web sites provide lists of colleges and universities that offer degrees and certificates in nanotechnology, nanoscience, and nanoengineering:

- associate degree and certificate programs: <https://www.nano.gov/education-training-workforce>
- all academic levels: <http://www.trynano.org/resources/universities>
- bachelor's degree programs and higher: <https://www.nano.gov/education-training/university-college>

The Job

Nanotechnologists work in industries that use nanotechnology. For example, those employed in the alternative energy industry work with scientists and engineers to improve fuel cell efficiency and develop self-cleaning coatings for solar cells that reduce maintenance time and costs.

Nanotechnologists working for the National Institutes of Health have helped to develop nanoparticles as drug delivery systems to directly target tumors. In the food packaging industry, nanotechnologists help develop nanosensors that can detect food-borne pathogens. Many other industries use nanomaterials, including cosmetics (for emulsions and pigments), textiles (to produce garments that are more durable and dirt- and water-repellent), and construction (to create self-cleaning glass and stronger concrete). Although nanotechnologists work in a variety of industries, all technologists perform the following duties:

- inspect and measure thin films of carbon nanotubes, inorganic coatings, and polymers using a variety of techniques or analytical tools
- develop or modify wet chemical or industrial laboratory experimental techniques for nanoscale use
- produce images or measurements using tools or techniques such as atomic force microscopy, optical microscopy, particle size analysis, scanning electron microscopy, or zeta potential analysis
- process nanoparticles or nanostructures, using technologies such as ultraviolet radiation, microwave energy, or catalysis
- prepare capability data, training materials, and other documentation for transfer of research processes to production
- prepare reports for scientists, engineers, project managers, and company executives
- collect or compile nanotechnology research or engineering data

- contribute written material or data for grant or patent applications
- install nanotechnology production equipment at customer or manufacturing sites
- supervise technicians engaged in nanotechnology research or production
- analyze the life cycle of nanomaterials or nano-enabled products to determine environmental impact, and address any issues that arise

ACS Citation: *Nanotechnologists:Requirements - Vault*. vault.com.

<https://vault.com/professions/nanotechnologists/requirements>.