Quest #606
The Scientist

(Mindy Viecknicki)
A lot of people think that science is memorizing things.

(Sean Todd)
Science is a way of knowing.

(Sonya Bates)
Knowledge gained by experience.

(Toby Stephensen)
Study and understanding.

(Karsten Pohl)
Just to be open to the world.

(Rosemary Seton)
Being passionate about something enough to want to go out and answer a question about it.

(James Harper)
Questioning… questioning authority.

(Bethany Holms)
Ask the question first and then go out and figure out how to answer it.

(Ann Zoidis)
To answer a question, not necessarily for an application.

(Dan Dendanto)
A consistent and proven approach towards testing the reality around us.

(Linda Greenlaw)
Hi, I'm Linda Greenlaw

We tend to imagine scientists as coldly efficient men in sterile lab coats and rubber gloves or else demented, madmen who blow things up.

But what's it really like to be a modern scientist?

On this QUEST, we'll hear some of the questions that real scientists are asking right here in Northern New England. From the atoms and molecules of nano-science…to the largest creatures on earth, how do scientists explore our world?

(Mindy Viecknicki)
I have a two and a half year old daughter, who keeps me really busy.

My family tells stories about being at the mall where there was a dolphin in a tank, and that I wouldn't leave unless they took me away kicking and screaming because I wanted to hang out with the dolphins.

(Narrator)
Mindy Viecknicki is one of over a dozen scientists who work at Allied Whale in Bar Harbor, Maine. Focusing on some of these scientists, we see the challenges modern biologists face.

(Ann Zoidis)
I started out studying a lot of terrestrial animals, but when I got my first break in marine mammals, it was like, boom, I just did that for about fifteen years without looking back. My father's Greek and we spent a lot of time in Greece. And I saw at a very young age all kinds of marine life, and I'd go out with the fishermen and these long line nets. I just have pondered – is that why I was drawn to this field because of really seeing the animals – seeing what they go through – and seeing human interactions with them?

Marine mammal science, it's a relatively new science –just started really in the early nineteenth century, and probably wasn't until the 1940's and '50's where it became, "Let's look at these animals without killing them."

(Narrator)
Allied Whale is affiliated with College of the Atlantic in Bar Harbor, Maine. Unlike the stereotype of cold, analytical scientists, all the men and women at Allied Whale are extremely passionate about their work – a passion that often starts at a young age.

(Dan Dendanto)
I have been interested in marine biology, particularly the study of whales – from a very early age of six or seven years old, and I suppose it was probably something picked up off of the TV. The first thing that attracted me to marine mammals undoubtedly was their size. They had the sort of allure that dinosaurs do for so many of us in that they were of such immense scale, so different than our own and that's still is very interesting to me today but I think what is more profoundly amazing about the marine mammals is their adaptation for the ocean environment.

(Sean Todd)
I always wanted to be a whale scientist. From when I was very, very young and I happened to have a wonderful grandmother who just kept saying 'You can be a whale scientist if you want to be a whale scientist.' I was only five years old at the time but she told me that and somehow that stuck.

(Sean Todd)
It turned out that there wasn't anywhere in the United Kingdom where I studied where you could study specifically whales, mostly because the United Kingdom killed most of their whales through the whaling process.

So what I chose instead to do was to focus on Marine Biology and Oceanography.

(Narrator)
It's understandable how many of the biologists at Allied Whale fell in love with their subjects – but what inspires someone like a chemist or a physicist?

(Jerome Claverie)
Somehow I think being a scientist helps me play music. Often I see some chemistry formulas that which are written with musical notes. In order to be a good scientist you need to most possibly be open minded.

When you think about music and science, obviously music is very close to my heart. It's hard to put rational words about it. The creative process is the same both sides of music. It's like you are free to do whatever you want either with your musical instrument or with the science that you practice. You are not limited actually by anything.

(Narrator)
It's no wonder that Jerome Claverie is a creative person. Chemists like Jerome are coming up with ideas for re-shaping matter in ways that would challenge any artist's creativity. A member of the Nano Group at the University of New Hampshire, he collaborates with physicists in the new field of Nano science, the study of objects that are close to the size of atoms and molecules.

(James Harper)
So let's meet in the lab on Friday at 1 o'clock and we'll take it a little further….

(Student)
Okay – see you later.

(James Harper)
I've always been interested in science; starting with astronomy…I did have a little telescope when I was a boy so I got to look at things a long way away. But I think I always wanted to get my hands onto things and actually do experiments in the lab and make changes and learn about properties of materials that you could actually manipulate.

(Narrator)
When nano-scientists like James Harper apply their science to practical problems, it's called nano-technology. Already nano-technology is being used in products from paints to sunscreens. Because he's interested in applying science to useful applications, James Harper is as much an engineer as a physicist.

(James Harper)
Some people make a distinction between engineering and science. I don't see them as all that different.

I went to work at IBM in the research division and worked there for 27 years. So most of my career I was working with materials that go into computers and electronic devices.

(Narrator)
Another physicist working in the Nano-Group at UNH is Karsten Pohl. Of all the sciences, the career of a physicist seems the most varied and the least understood.

(Karsten Pohl)
When we talk to our students in the physics program, sometimes we have little difficulties actually portraying physicists to them and showing them what physicists really are because the only physicists, of course, they have met are their high school teachers and their college professors.

(Narrator)
Physics provides a well rounded scientific background, so that a degree in physics leads to careers as varied as work with NASA, the weather service or computer manufacturing.

In his native Germany, Karsten Pohl vexed his parents when he left the clear career path of electrical engineering to study physics.

(Karsten Pohl)
When I graduated high school I was very interested in engineering type science…but then I realized that physics was back then, still is, for me the science which may be the most general and if I get an understanding of the physical world I would be pretty well prepared to understand engineering problems just as well as maybe philosophical problems.

(Narrator)
Nano science lives at an intersection between the atomic world of the physicist -- and the world of the chemist who studies and creates molecules.

(Glen Miller)
I got interested in science pretty late probably compared to most people who ultimately become scientists. It wasn't really until high school when I had chemistry class that I was ultimately hooked on science and chemistry in particular. Before that I was certain I was going to be a journalist.

I started out as more of a classically trained organic chemist, and I took my first post-Ph. D. position at Exxon research and engineering company. And literally within a few days of arriving, intending fully to work on a very different project, the discovery of fullerenes was announced.

(Narrator)
The discovery of fullerenes was one of those happy accidents when scientists are performing pure science, with no particular application in mind. But fullerenes would prove to be key in the birth of nano-science. Shaped like a soccer ball, the most famous fullerene has 60 carbon atoms -- it's called carbon-60 or Buckminster Fullerene after the architect of the geodesic dome since it looks a bit like one. Bucky Balls as they are also called are not the only fullerenes – they come in many shapes and sizes, but they are all hollow and composed entirely of carbon atoms.

(Glen Miller)
So I started working with fullerenes, that was maybe 1990, still a few years before I'd heard the term nano-science or nano-technology and before some of the ideas that we now consider consistent with nano-science really caught on.

(Narrator)
How small is small in the nano-world? Instead of measuring with an inch or a centimeter, nano-scientists use a nanometer, or a billionth of a meter…With this scale, you find a flea is about a million nanometers. A human hair is about eighty-thousand nanometers wide…even a single red blood cell is…about seven-thousand nanometers across!

(Art Greenberg)
When we talk about nano-science, we are really talking about putting together structures that are on the size of atoms and molecules and actually making devices, which basically are of molecular size.

(Narrator)
How does a new scientific field like nano-science get started? At the University of New Hampshire, the Nano Group falls under the College of Engineering and Physical Science. The school's Dean, Arthur Greenberg, himself a chemist, has written extensively about the origins of science with its roots in alchemy and religion.

(Art Greenberg)
There's an irony in that chemistry developed its atomic theory at the very beginning of the 19th century and at that point it was a purely chemical concept. It took 100 years for the physicists to accept atoms and molecules as real. So in a sense, chemists sent out the challenge to the physicists. Here are atoms, now you show us that they're real. But in 1959, Richard Feynman, who is a Nobel Prize winning physicist, threw a challenge out to the chemists and he gave a talk called "Small is Beautiful" where he talked about designing machines that were basically made of atoms and molecules.

(Narrator)
With the invention of the scanning, tunneling microscope in the 1980's scientists could finally get a look at individual atoms and attempt to manipulate them.

(Art Greenberg)

One of the famous scientific icons of our age is what is known as the quantum corral. And that was made by IBM scientists who actually placed, one by one, 48 iron atoms into a circle. That ability, to manipulate atoms one by one, was one of the critical advances.

(Narrator)
Imagine the incredible challenges scientists faced as they first attempted to manipulate atoms and molecules in their infinitesimally small universe.

But what about a whale biologist? Was it any easier to find a way into the world of the largest animals on earth?

(Steve Katona)
I started Allied Whale with Sam Elliot back in 1972. At the time it was called the Whale Workshop, it really is a collection of research projects initiated and done in a collaborative way.

(Steve Katona)
You know that hump-backed whale that was disentangled in Nova Scotia. I've been telling people that there was 15 lobster traps on it – but you know how many there really was?

(Staff)
There was way more than that …

(Steve Katona)
There was 57….

(Narrator)
Now president of College of the Atlantic, biologist Steve Katona set in motion a vision for Allied Whale based on a collaborative model. Unlike universities where a hierarchy would separate professors, students and amateur naturalists, at Allied Whale, everyone who had a passion for whales could get involved in the research.

(Ann Zoidis)
Do we need to clarify with Andrew before we go on this closure trip – if we can pull off propane…?

(Sean Todd)
Are they truly empty or are they like dregs….

(Judy Allen)
We really act as a team; we meet as a group to make decisions about research directions like when we're talking about the next field season.

(Narrator)

One of a dozen or more paid staff, Judy Allen has been with Allied Whale since the early days.

(Judy Allen)
People bring to the table their ideas. We don't have a clear director this is somebody who's laying out the direction. We really decide as a group what that's going to be.

(Ann Zoidis)
For those of us especially who've been around for a decade or more, you know, these people are not just your co-workers, we're friends, we're family – we're a community.

(Group singing)
"Happy birthday to you, happy birthday to you. Happy birthday dear Judy…."

(Mindy Viechnicki)
I'm so fortunate in that I work for Allied Whale, – oh my goodness, they're extremely supportive, of family…I think balancing work and family is extremely challenging when there was an interval of time when I thought; "no, it's either or" but it's working, it's working great.

(Steve Katona)
In 1972 when we took our first students, the large whales were still being hunted…and nobody knew what whales were present in the Gulf of Maine.

So the scientific part of Allied Whale was to begin assembling that information. We developed forms which we sent out by the thousands …and the idea was when you saw a whale you had to circle what the blow looked like and what the head looked like, or did you see the tail and what it looked like and send it back.

And in 1976 we published the first Humpback whale catalog and lo and behold one of the amazing results was, that a whale that had been photographed in Bermuda…showed up at Mt. Desert Rock…and you could see quite clearly it was the same whale and so we had our first long distance migrational link…and we knew we were off and running.

So that first catalog which included I think 110 whales has now grown to many thousands and Allied Whale is now the central curating facility for photographs of humpback whales taking anywhere in the North Atlantic Ocean.

(Narrator)
The whale catalogue is a deceptively simple idea that solves many problems encountered by previous whale researchers. Whales, being long-lived species that travel huge distances, are next to impossible to track. They could only be identified when they were killed.

Instead, with Allied Whale's method, a student or staffer matches new photos they receive with huge catalogues of existing photos – while never harming the whale.

(Bethany Holm)
Anyone can send us a photo of a whale.

If we find a match then we contact the contributor again. And say we found a match then with their permission we put the photo up on our website so that other people can actually compare their photos from wherever they are. The idea is to share data and really facilitate collaboration.

(Ann Zoidis)
There is an interesting development in science nowadays with the whole internet, historically as a scientist you held your data to yourself and you didn't really share it, well now we have this unbelievable tool, the internet.

(Narrator)
The coordinator of the catalogue, Rosemary Seton, is always in touch with her colleagues at other whale study centers.

(Rosemary Seton)
… See that other batch has a close-up of the tail…

(Rosemary Seton)
For humpback whales in the Gulf of Maine, there is an official humpback whale naming party. The reason for naming them has an actually important function and that is as a memory aid…and we try to name the humpback whales based on markings on their tails typically. Sometimes we have lineage names, for example, there is a humpback named Olympia, one of her calves is named Sparta…Actually Sparta is my favorite humpback.

(Narrator)
The information assembled by whale scientists forms the basis for management decisions. When creating their regulations, organizations like The International Whaling Commission look at issues such as how many whales are in each species and how they migrate. Allied Whale's cataloguing work has been key to assessing the health of whale stocks in the North Atlantic

(Glen Miller)
At home I have 5 children who keep me very busy, and my wife very busy. A typical day for me is to get myself up early in the morning and getting ready to start moving the herd in the right direction. Which means getting children up and out of bed and dressed and getting them breakfast and making lunches and ultimately driving them to their various destinations. Once that's done, I sort of take a big sigh and then I do the easy part of my day which is my work.

(Narrator)

Women are not the only scientists who struggle to balance their home and work lives!

(Glen Miller)
There are some times about 7 or 8 o'clock at night when I just feel like collapsing. But for the most part, the way that I stay energized is to stay interested. It's easy to get up in the morning and to get prepared to go to work because I'm excited to get there.

(Glen Miller)
So what if we put this in the dark….

(Narrator)
Unlike Allied Whale where students and experienced scientists are on equal footing, universities are set up with specific duties and hierarchies. The responsibilities of most scientists like Glen Miller are threefold. They teach…they conduct research… and especially at a public university, they are expected to do outreach in the community. Usually, they also need to write proposals to get funding for their research.

A professor on a tenure track, like Karsten Pohl, has five years to prove himself in all these areas. In the next nerve-wracking year, his work will be reviewed and he'll either be hired permanently or let go.

(James Harper)
We're making these mixtures….

(Narrator)
Some scientists, like James Harper, who is head of the Material Sciences Department, also have additional administrative duties.

However, others, like Jerome Claverie, are not required to do classroom teaching at all.

(Jerome Claverie)
There are a small body of professors who are called research professors. We are here only to do research. The way scientists and I think many other people do research is that we do research by collaborating, by advising graduate students. So we have students actually in our laboratory but we do not teach we are just advisors. They work on my research with me and we see each other every day when I'm here.

I think it's not only essential but extremely enjoyable to collaborate with junior scientists and contrary to what they may think, I learn as much by them as they learn by me. I have never had the feeling of doing a job. I work at home and I would work during vacations…It's not a job it's a passion.

(James Harper)
I actually live close enough that I can walk into the campus, which is great. So I walk in to my office, usually need to prepare for a class that will be going on that morning…

I also enjoy seeing the students become more independent in the lab where they can run the equipment, they can do the measurements and they come up with great ideas as to what to do next. And seeing them become independent scientists is very rewarding as well.

(Narrator)
Grad students often choose to work under a scientist who will help them with their own career goals.

(Anne Marie Shover)
One possible application for this would be in creating new materials for space sensors. I'm more interested in going to work for NASA when I'm finished here. So I'd like to see if I can get involved in the manned space flight somehow.

(Karsten Pohl)
Nobody can tell you to go out and do this and this and this and then you will become a scientist. That's not how it works, especially in a field like physics where you can go off in many directions.

(Glen Miller)
In any science project…it's very important to have students involved. They are ultimately the ones who do the work. People like me sit around and write papers and write proposals and talk about how things should work but it's ultimately the students that make them work…So they are an integral part of the science enterprise in this country and all over the world.

(Glen Miller)
In my lab there are graduate students and undergraduate students and post doctoral fellows who are working to make molecules. As an organic chemist, we're interested in making new molecules that is some interesting properties…. To mix the right chemicals together in the right proportions in order to initiate some sort of a chemical reaction that creates a new molecule.

After they've run each of these reactions they would be responsible to figure out what happened at each stage.

(Student)
You just need one of these to get this thing started. Then you're constantly producing these hydroquinone moieties.

(Glen Miller)
So let's go ahead and draw the next one.

(Student)
So the next one we'll add in….
(Glen Miller)

So let me ask you – after the first step which you've run at room temperature for 3 days did you get a precipitate?

(Student)
It didn't appear that way…

(Glen Miller)
Everything was still in solution, it was still homogeneous…

(Student)
It was a really dark solution – it looked like a really dark solution…

(Glen Miller)
All right, good, thanks Ryan…

(Narrator)
How does the Nano Group see their results when they work at a size smaller than the spectrum of light? Many of the problems that these scientists have to overcome deal with seeing their work as much as doing it. Some people don't realize that modern scientists have to be multi-talented, often designing or even building the tools and microscopes that allow breakthroughs in their field.

(Glen Miller)
New molecules have their own unique structure. It's essentially the skeleton of the molecule. We can't see the molecules, of course, so we have to use spectroscopy…to tell us exactly what the molecule is, what its shape, its skeleton is. One of the spectroscopes which we utilize over and over again is NMR, or nuclear magnetic resonance spectroscopy.

It is essentially the same technology that is used by the medical industry to do MRI, magnetic resonance imaging of people…except that we're imaging, if you will, molecules rather than people.

(Karsten Pohl)
You realize that you can't fly blind in this business you really have to know where the atoms are to appreciate what kind of structures we have…So, we have built a scanning tunneling microscope which basically uses the interaction of a conducting very, very sharp tip.

(Narrator)
Housed in its space-age looking vacuum chamber, the tip itself doesn't seem all that high-tech to the naked eye. However, the scanning tip is almost perfectly sharp, coming close to being only one atom at its point! As it moves over the atoms on a surface, it plots a contour of the atoms and the spaces between them.

(Karsten Pohl)

Of course, the physics has been understood for almost 80 years since the introduction of quantum mechanics. But why hasn't this instrument been built 80 years ago, was of course we didn't have the mechanical engineering understanding of how to build motors which would control a tip and move a tip by one angstrom at a time.

One of our main goals is to build a microscope which is able to find the same atom again after we have removed the microscope from the sample.

My students are building the scanning tunneling microscopes in our laboratory and we are getting very good in building very, very small things. So I always tell my students, "If you don't get a job you can always move to Switzerland. I think every watch company will be happy to employ you."

(James Harper)
My research now is in thin film materials. When I say thin films I mean anywhere from a few atoms thick up to thousands of atoms thick. We're in the process of trying to control where the atoms go. We basically deposit atoms onto a surface in a vacuum chamber. We have to pump the air out of the vacuum chamber, we have to make sure it is very clean, otherwise we end up just getting contamination on the surface. So if the system is nice and clean, the pressure is nice and low, we can transfer atoms onto the surface in a very controlled manner…

Just to see the atoms and the structures at that length scale, we need devices like an electron microscope just to see what we've made.

(Narrator)
At Allied Whale, the scientists also have difficulty seeing their subjects – since marine mammals spend most of their lives underwater. It's still a mystery where some, like right whales, go for much of the year. So, in addition to cataloguing the whales from photos they receive, the scientists at Allied Whale go out into the field to gather their own information.

(Dan Dendanto)
A typical day at Allied Whale really depends on the time of year. In the summer time, we're involved in field work – data collection, there's only a couple of months which are really very reasonable for working in small boats. And so a day might be consumed with understanding the weather patterns

(Ann Zoidis)
We all innately get up and look at the weather, no matter what. And I have a marine radio in my house, so I'll listen to the marine weather report. And you always assess, 'is this a day that we could work?'…

(Narrator)

Allied Whale operates a field station on Mount Desert Rock, more than 25 miles off the mainland. The furthest-eastern piece of land in the US, this barren 3 acre island is directly in the path of migrating whales, birds and other marine life. More than 1000 seals will gather on the rock at a time.

(Bethany Holms)
I've spent 3 whole summers on Mount Desert Rock…. It has a light keeper's house where we stay when we are out there doing our research, as well as a generator shed….It's not for everyone I think because it's so isolated out there, but I really enjoy it out there. It's great to get away and to really be able to focus on your work…

(Ann Zoidis)
We're all independent mavericks, who want a creative day. Especially when we're out at Mt. Desert Rock, every single day is different, unequivocally –the weather's different, the tide's different, the boats are breaking or not, or certain whales are showing up…

(Narrator)
When the weather's right, the scientists set out in small Zodiac boats. Chris Tremblay, a former student at College of the Atlantic pilots one of the boats.

(Cris Tremblay)
We'll go out from our island and we'll stop, turn the engine off and listen for whale blows that's really a very effective way to find whales.

(Ann Zoidis)
Being out in the Zodiacs is the greatest part of the job, and I work on a lot of different boats actually, you know, larger boats, fiberglass boats, hundred-foot boats, but the Zodiacs are where you are the closest to the animals.

(Cris Tremblay)
… Fin back whales are very fast and…they are incredibly agile, they can turn on a dime, you would really be surprised, and a lot of times…they're easily approachable because they are feeding and they don't care about you… I would say there is a level of harassment; I don't think it's that high with our little boat.

(Ann Zoidis)
There are ways to minimize your impact in terms of how you drive, in terms of how you shift your gears and your approaches to the animals…

The reason the gears are important is they hear that underwater, and if you take a long time to move from neutral to reverse, there's a ratcheting that happens with the propeller, and it's very loud underwater. And it's disturbing to the animals.

(Narrator)

For humpback whales, the scientists position themselves behind the animal, because a photo of the animal's tail or fluke will identify it. Finback whales, on the other hand, require about four photos for identification. The finback is the only animal in the world with asymmetrical markings – a consistent difference of color on each side of its head – usually white on the right - black on the left. They tend to come up for several breaths, traveling in a straight line, so the scientists have to gage the animal's path to get all the photos they need.

(Cris Tremblay)
When we're on our research boats we will take notes of location data…it can be sort of rough to take notes in that atmosphere.

(Narrator)
Society often benefits from the scientist's search to find answers to his or her questions, but what many people don't realize is that scientists can spend more than half their time raising the money to fund their work.

Recently, Glen Miller secured a large grant to create a Nano Scale Science and Engineering Center, a collaboration between UNH, Northeastern and U Mass Lowell. Rather than trying to make a nano-sized product, the scientists are more interested in coming up with the technology to make nano-manufacturing possible, much like building machines that would make a factory run.

(James Harper)
The focus of that center is to find ways to make templates from which you can manufacture multiple copies of nano scale devices…If we can create a template, like a master pattern from which we can then make multiple copies, then we're on our way to a manufacturing approach for devices that have these nano scale properties.

(Narrator)
Pushing atoms around one at a time is not only ridiculously labor intensive and time consuming for large scale manufacturing, but the consistency of the product would be hard to duplicate.

(Karsten Pohl)
You basically have to step back and take the physicist's approach to solving problems by basically looking for what does nature do for us. For instance we can get beautiful pattern information in the deserts of Saudi Arabia where the wind interacts with the sand and makes these beautiful stripes on the side of a dune…So can we make ripples which we see on a sand dune on a much smaller scale which is only maybe a few nanometers apart from one another?

(James Harper)
We can't get in there with any type of manipulator and tell the atoms exactly where they should line up. We have to find ways where the atoms separate spontaneously and line up

by themselves and understand the forces that can make that happen. So this is a theme that goes across a number of different projects in the new center.

(Karsten Pohl)
So what I'm doing is I'm looking for pattern information on surface of metals.

Now gold is a very popular example.
When I take a chunk of metal and cut it in half then I expose a pristine surface of this metal.
What happens is that the surface is a very different beast from the inside of a material because you cut a lot of bonds when you take a piece of metal and cut it in half…so the effect of that is that these atoms, of course, now have to arrange themselves because there is no room. Just as if you would take a carpet which is a just little bit too large for the room and try to lay it down. In order to make the carpet fit, of course you have to make ripples in the carpet. So the very same picture applies to the gold surface so you get ripples in this particular gold surface. And the nice thing about it is that these ripples are perfectly ordered. They look like the herringbones on a tweed jacket with elbows connected by straight lines. Now here you have a naturally formed pattern. The distance between these herringbone stripes is only 2 or 3 nanometers and it's perfectly ordered.

(Narrator)
By harnessing nature's ability to form patterns like these, scientists can create self-assembling nano-templates. The scientists don't have to push individual atoms into position; nature does it for them on a massive scale.

(James Harper)
If we can make these patterns form spontaneously, then what we'll do is work with Professor Glen Miller, the collaborator in the project, and he brings molecules down onto the surface that will attach selectively to some of these regions but not to others.

(Narrator)
Like magnets that attract or push away from each other, certain chemical molecules are attracted or repelled from the atoms on the patterned surface.

(James Harper)
It's almost like putting ink onto a printing press. We've got the type, and you put the ink on…the next thing you want to do is make the molecules now attach to a new surface that we bring along.

(Glen Miller)
If we can transfer those objects onto a new surface in the same pattern as the nano-template then we can reuse the nano-template and in principal we could do this over and over and over again to create these patterned surfaces.

(James Harper)
My work will be mainly on creating the patterns; Glen Miller will be developing the chemistry for the molecules. Professor Karsten Pohl will be working on different patterning techniques. And together, we think that we can make several different types of templates for multiple copies of the pattern that we've generated.

(Glen Miller)
I think there is a great potential for nano technology to impact our lives.

(Narrator)
How will these templates be used? One application is to store information on computer chips. Right now, the micro-chip industry can't print much smaller circuits because they're limited by a lithographic process. Nano-templates have obvious potential use in assembling much smaller chips. Other applications would be to make medical devices. For instance, a nano-device could act as a sensor in the body, warning of disease or monitoring medications.

Jerome Claverie is also working on medical uses for nano-technology. His focus is on finding a way to give drugs orally instead of by injection.

(Jerome Claverie)
We are interested in delivering insulin for diabetic people via the mouth.

(Narrator)
If taken orally, insulin would normally be destroyed by the stomach before it could reach the blood stream.

(Jerome Claverie)
What we are doing is encapsulating insulin with one of these nano particles The nano particle is designed in such a way that it can go through the stomach and during this time without being harmed.

Typically these spheres are 1 million times smaller than the width of a hair. My laboratory is really trying to develop a toolbox to learn how to make these nano-particles and small spheres

(Narrator)
Other nano-tech applications make use of "nanotubes" which are like fullerene carbon atoms, except they are shaped like a cylinder.

(Glen Miller)
Nano-tubes have very special properties that get people excited. And they fall in two categories, mechanical properties and electronic properties. The mechanical properties are such that nano-tubes are lightweight but very high strength.

(Narrator)
General Motors is already using nano-tubes in the polymer manufacture of van running boards because the nano-tubes add strength while keeping the car's weight down. These same properties have led to everything from lightweight, high strength tennis rackets to clothing that can't tear.

(Glen Miller)
The electronic properties of nano-tubes are a different set of properties all together but very exciting as well. Nano-tubes could be used as either molecular wires or as transistors or some other type of component in a nano-device.

(Narrator)
Already consumers can buy nano-tech fabric that dries quickly, protects against stains and UV rays, chases away bugs, or even represses human scent. In the future, the ultimate camouflage fabric could change color based on the environment, or be programmed to clean itself overnight. But nano-technology goes beyond any single product. Theoretically, anything could be replicated -- from diamonds to water to food – as future nano-technologists build anything from its atomic components.

(Art Greenberg)
When people talk about nano technology and nano manufacturing being a revolution, I actually do think that that's a fair statement.

But to be frank with you, one of the things that makes this field interesting is that I don't think all of the science is yet known. The area is so important that we have to jump into it even as there are a lot of very fundamental science questions that remain to be answered.

(Narrator)
No scientific inquiry is a sure bet. Most scientists expect surprises in their results.

(Dan Dendanto)
I'm very interested in understanding how societies work, both human and mammalian.

My major interest in fin whale population biology is to understand how individuals relate to one another

(Narrator)
As well as working at Allied Whale, Dan Dendanto is a grad student at the University of Maine. For his research, he uses genetics to understand how finback whales are related to each other.

(Dan Dendanto)
The genetics work is really based on the idea of taking living cells from the organism and then extracting DNA – We use a technique of a crossbow and a small biopsy punch to remove a small portion of skin, about the size of a pencil eraser, really.

(Ann Zoidis)
What we have here is a biopsy sample of a fin whale and you'll see the blubber hanging down. There's teeth inside this tip that keep the sample inside embedded inside the tip is the skin….

(Dan Dendanto)
From that skin we can extract pure DNA…once we have the DNA, we can conduct a number of different kinds of tests on it, to understand more about it. The sex of the individual, the genetic affiliation of the individual, even something that might speak to its species relationship.

(Ann Zoidis)
I think we've all at some point or another asked ourselves, how do you feel about shooting this arrow into the whale? There is some conflict, because you don't want to hurt the animal, we're all very sensitive to that.

(Mindy Viechnicki)
Ten years ago I would have never shot a crossbow, I mean I just would have thought, 'that's horrible, you're shooting a whale, what are you doing, that can't be worth it.' But now I've seen the science that's connected with that, I've seen how the papers connect with the management tools. I've seen how that information can come back and help those animals. …I definitely think that the benefit outweighs the cost of that.

(Narrator)
A piece of the same, small sample taken from a whale is also used by Sean Todd. He looks for specific molecules in the whale's cells called isotopes. By an analysis of these he can actually tell what the animal has been eating.

(Sean Todd)
The idea that you can take a plug of skin from an animal and say something about what it's having for breakfast is amazing.

(Bethany Holm)
When we collect our samples for isotopes first we freeze the skin sample to store it until we're ready to use it, I'll thaw it and grind it up very fine and then we need to take all of the fats out of it, the lipids.

(Sean Todd)
We have broken at least two machines now trying to pummel this stuff. And every time I phone up the chemical company and say you know, we need a new machine, and they say, well what are you using to break all these machines, I'm saying well it's whale skin, and they don't believe us.

(Narrator)
Once baked and chemically processed, the whale sample becomes a very fine dust. It's sent to a lab for analysis and chemical ratios are returned to Sean Todd for his study.

In this case, marine biologists have assumed that Humpback Whales and Finback Whales eat the same food, because they are often seen feeding side-by-side.

However, by using isotope analysis, Sean Todd finds some surprising results.

(Sean Todd)
When you look at the isotope record, the isotope record says 'yeah Humpbacks are eating herring, but Finn Backs are eating more plankton.' Which is kind of a neat answer because it implies that these two species of animal that visit the Gulf of Maine, have found a way, coincidently or not, to partition the resources.

When Humpbacks come up into the Gulf of Maine they are starved. They're here exclusively to feed. It is a very critical period for them. Some figures for Southern ocean populations suggest that a Humpback, for example, may loose as much as half of its weight during the winter period when it is down in the Caribbean and then when it comes back up to the Gulf of Maine it would have to double its weight.

So knowing what they feed on, and then asking the question, 'Are these populations of prey stable?' is a very important question when we consider issues such as conservation management of the species, remembering that all whales, whether they are endangered or not, are protected by the Marine Animal Protection Act, which demands that we manage these species.

(Narrator)
Like the biologists at Allied Whale who weigh right and wrong when using a crossbow in their research, chemists and physicists consider ethical issues in their work as well.

(Glen Miller)
There certainly are a lot of issues around what we could call the societal impacts of nano-technology and part of that is because it's a new field, it's a new technology and there's always some uncertainty and some fear of new technologies, as there should be.

In the case of nano technology, I think there are some fears related to health effects, for example. What if these nano scale objects should somehow be airborne and people are breathing these. What would the health effects be?

And these are legitimate concerns…So it's very important for this field to address these issues, to study the health effects and at an early stage.

(Narrator)
As well as fears about health issues, there is always concern that a new technology can be used for purposes of war. Recent books and movies have roused the public to worry about the power of nano-particles to self-replicate into minute robots that can enter people or take over, turning the world into a grey goo. However, this scenario is highly unlikely.

(Glen Miller)
It's good for people to be skeptical and it's good for this science and this technology to develop with an awareness of the skepticism and the concerns that are out there. I think if we do that, then in the end we will have a robust technology that people are comfortable with.

(Narrator)
As the latest, greatest buzzword making science news, nano-technology appears to be the new darling of the investment community. Already markets related to nano-technology are estimated to be worth 150 billion dollars a year. With projections of a trillion dollar market in 2010, nano-scientists find themselves riding a unique opportunity for funding their scientific interests. But what happens to the scientists who are working on topics not in the news?

(Karsten Pohl)
Funding drives science very, very much, I have to admit because you have to realize that all of our Ph.D. students are funded on research grants. So if we are not able to attract funding for our research projects, you cannot educate graduate students. And that is something which really many people don't realize, that governmental funding is the key in guaranteeing the success of our graduate education in this country.

(Sean Todd)
I think the days of pure science are for the most part gone. The trick is if you have a question that is more in the pure science realm, the trick for you as a grant writer, is to try to think of a way to frame that so that it would appeal to an applied technologist of some kind.

No one is particularly interested; say for example, in how loud a ship is. But when I say, ah! But what if the loudness of a ship is directly responsible for whether or not a whale can detect it in time to get away from it, then you've entered the realm of a conservation issue.

(Mindy Viecknicki)
They both include an 8x10 color photograph as well as a brief history and a composite sheet which shows all the distinguishable markings of your whale.

(Narrator)
The scientists at Allied Whale have become very creative in funding their work. They have created an adopt-a-whale program…and run a whale museum in Bar Harbor.

Toby Stephenson, another scientist at Allied Whale whose passion is educating the public about marine life, puts together many of the exhibits at the Allied Whale Museum.

In addition to finding funding for their research, scientists often have to be creative at finding ways to fund themselves and their families.

(Ann Zoidis)
It's not a very lucrative field. And as you get older, you're not making as much money as a lot of your peers, and… It's challenging; a lot of people work nine-to-five and then can go home and can relax, and in science you always – there's always something you should be doing: writing a paper, writing a grant, reviewing your data.

(Narrator)
Dan Dendanto supplements what he calls his "grad school habit" by preparing marine skeletons for display in museums. He and his crew are assembling this 45 ft. sperm whale for an exhibit at the Nantucket Whaling Museum.

(Glen Miller)
A sound so concussive and so loud that that…

(Narrator)
There is, of course, as much variation in scientists as there is in their work and in how they deal with their individual circumstances. What is remarkable is the difference between the passion and precision required for the work and the public's perception of the scientist.

(Mindy Viechnicki)
Certainly it's romantic to go out and look at whales, and it's inspiring, and it's exciting. But, at the same time, the information that we're gathering from these animals is telling us about the environment they're in, it's telling us a lot about what we're doing to that environment, and I think we need to take all that information really seriously. They're not just romantic animals to go and have fun looking at. They're indicators of how we can strike a balance with our environment.

(Sean Todd)
As a scientist I have been trained to be very objective, and I'm supposed to view these things as animals and not go anywhere else other than that. But it's very difficult when you spend time in the presence of these creatures, not to start being a little bit emotional about it and start to care for these animals. These are the largest animals that ever roamed the earth, with the exceptions of dinosaurs, and in fact, a couple of our whales exceed the size of dinosaurs.

Yet, they're mammals, they're not so far from you or I, if you are to cut one up you will find most of the same things inside their body that you would find in our body. So there's a kind of a kinship there in someway.

(Dan Dendanto)
Given the frustrations – because there are always feelings of frustrations, whales not cooperating with their behavior, weather not cooperating, boats and equipment not cooperating, that's all very frustrating. But when you take a moment and escape the detail of what you're doing, just a very inspiring feeling and exhilarating to have the privilege to be where you are.

(Narrator)
As society becomes ever more complicated and we look to scientists to help us sort out the truth, the public's understanding of science itself – both its majesty and its limitations --- becomes absolutely essential.

(Glen Miller)
If there's one misconception, I think it's probably that science is black and white. Things are either right or wrong and there is never any gray area in between. And that is certainly not the case. Science is almost completely gray area.

I view myself as being quite analogous to a lawyer. A lawyer goes into a courtroom and tries to build a case. In science, it's much the same way. We build a case based on all the evidence that we have collected. The difference is if we have made some conclusions that are not completely consistent with the evidence, there will always be some other scientists out there who will read the paper and point this out. So the court case, if you will, never ends.

(Ann Zoidis)
We just don't know what we can learn from something until we have assessed it and studied it, so let's continue to do that, let's continue to create that opportunity, let's continue to look at something, even though it's not immediately something that you can make a profit off of.