Deterministic

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So far we've been talking about modeling. We've been talking about modeling concepts such as the difference between the real world and the model world. We've talked about modeling paradigms such as rapid prototyping, for instance. And we've talked about modeling heuristics, for example, salami tactics.

But we haven't actually built a model, and the only way to learn about modeling is by doing it. So in this section, I'm going to tell you a story and out of that story will emerge the need for several different models that will get you started as a modeler.

What I want you to do is pretend that you are a modeling consultant. Suppose that you've taken the Principles of Modeling course, you've had a lot of experience, but I want to change the rules a little bit. To make this interesting, you're going to be a modeling consultant in 1000 A.D., with all the power of computing and the technology that we have, carried back to 1000 A.D.

So we're in the year 1000 A.D. If you were a modeling consultant, if you were really a high-tech nerd at that time, where would you want to be? What would be the most exciting part of the world to be in? China maybe? Maybe, maybe not. I would want to be in Baghdad. Baghdad in 1000 A.D. was probably the most exciting place to be. It was the center of the whole Moorish empire.

The most powerful man in Baghdad was, of course, the caliph, and the caliph of Baghdad, for the purposes of this exercise, we're going to pretend was a renaissance man, even though the renaissance hadn't happened yet. The caliph of Baghdad was interested in everything, and to keep his interests alive, he used to have his chief librarian read to him from a book or a journal every evening before he went to sleep. The chief librarian was a lady by the name of Scheherazade. And if you don't recognize the name, you better go back and read about the Arabian Knights. Scheherazade chose to read to the caliph from a book of ancient proverbs, prophecies by the Nostradamus of the world, and one of the items that she read went something like this, "When the roc no longer flies over the Arabian desert, the caliphs will no longer rule out of Baghdad." Let me repeat that... "When the roc no longer flies over the

Arabian deserts, the caliphs will no longer rule out of Baghdad." And the caliph was sort of half asleep listening to these prophecies, and suddenly he did a double take, and he realized that that prophecy affected the future of his regime. This was a threat to his descendants. So he sort of said, 'Hang on a moment, tell me about rocs." And rocs, of course, are giant birds that breed and live in the Arabian desert. They're about the size of a jumbo jet. I'll tell you a little bit more about rocs in a moment.

Anyway, the caliph had a troubled sleep that night wondering about what the threats to rocs were, and Scheherazade being a really good librarian chose to read to him the following night from a technical paper in the 1000 A.D. edition of a journal called *Conservation Biology*. And in that particular journal there was description of something called a population viability analysis, a PVA, which tries to predict what is going to happen to a population over time. And the caliph, of course, put two and two together and said, "That's what we need, we need a model. We need to build a model to tell us what's going to happen to the rocs in the next thousand years, say." Now, the population viability analysis is usually for a period of 50 or 100 years or something like that, but if you're the caliph of Baghdad and you're worried about the future of your regime, you're going to think big.

The caliph said to Scheherazade, "Who builds models?" And Scheherazade, of course, went to the Yellow Pages of Baghdad and looked up "ecological modelers" and there she found your name. And so you got a letter special delivery next day from the caliph telling you that you were going to be invited to the palace, along with some other ecological modelers - yours wasn't the only listing in the Yellow Pages - for a command performance on what it would take to build a model of the roc population. And what you were told was this. You were told that the roc model was to take the current population of rocs, and the current population of rocs was given to you as 703 rocs from a recent estimate, and you were to take that current population and project it for the next thousand years. You were to come up with your best estimate of how many rocs there would be in a thousand years time.

Then you were given a little sheet which told you something about the biology of the roc, and the information was that rocs only bred, only nested, in the Arabian desert. Rocs, as we said, were about the size of a jumbo jet. A roc only laid one clutch of eggs in its lifetime. So rocs would fly around, and there was a tremendous variation in the time at which they would build a nest and lay their eggs. There were some rocs that were really family oriented. And at a very young age would build a nest and lay an egg, or as many eggs as they were going to lay - lay a clutch. And there were other rocs that were kind of yuppie rocs that flew around and played and terrified people, and then suddenly realized, "Gee, it's time to settle down," and at that point

developed their nest and their eggs. But you need to understand, first of all, that rocs are neither male nor female. We don't quite know how the biology works, but basically every single roc is capable of building a nest and laying eggs. I don't know the social side of this, but that's what they do.

So, every roc at some stage in its life, which is highly variable, will build a nest and lay a clutch of eggs. They will then incubate those eggs very, very carefully so that the eggs hatch on the roc's 100th birthday. And just before their 100th birthday, the roc will fly off and look for a sailor and swoop down on a sailor, rip out the poor sailor's guts and take the body back to the nest for the chicks to eat when they hatch. And having done that, the roc will go off into the desert and self-destruct. That's probably where the legend of the Phoenix comes from, right?

Okay. So that's the basic biology of the roc. I doubt that that's enough information for you to build a model, but what I want you to do is to start thinking about what other information you would need in order to be able to develop this model to project the population from the current population to what you expect it to be in a thousand years time.

So your immediate task is to come up with a list of questions to take to a meeting at the palace with the caliph in order to get the information you need to design your model. At that meeting will be the world's expert on rocs. Now, if you think about it, who's most likely to fund roc research? Sailors, of course. This is where Sinbad the sailor comes in. Sinbad the Sailor is the world's expert on rocs, and that figure we gave you of 703 rocs was, in fact, from his famous paper on a roc census in Arabia. I should warn you, though, that Sinbad the Sailor was not a modern scientist. He was much like an old-fashioned naturalist. And when I gave you a figure of 703 rocs, there's no information anywhere in Sinbad the sailor's description of exactly how he got to that figure. We don't know how he did his sample. We don't know how he did the census. We do know all about the adventures he had along the way.

So, your purpose now is to break for about 10 minutes, come up with a list of five or six key questions that you think you need to ask in order to be able to design a model, and I want you to do one more thing, and this is a good habit to get into, prioritize your questions. Start thinking ahead to how you're going to use the information and put your questions in a prioritized list. Because the caliph is a very busy man, and at any stage during the meeting he might get bored or interrupted, and you want to make sure that you ask most important questions first. So let's take a break and meet at the palace in 10 minutes' time.

: Time to develop questions

Welcome to the palace. I'm the grand vizier. Behind me is the caliph on his throne. We were hoping to have Sinbad the Sailor here to answer your questions, but unfortunately he's off on one of his adventures. But I've done a lot of homework in reading his papers and talking to people who worked with him, so I'm going to try and answer your questions. I've got a list of questions gleaned from you the modelers in the audience, and I'm going to run through them and give you the best answers I can.

The first question is: **What is the current roc population?** Well, if you'd read the information sheet we gave you, the answer is 703 rocs. That's from a census done by Sinbad the Sailor. Unfortunately, I don't know how accurate that is. He tells us all about how he collected the data, but he doesn't tell us exactly what he did. When I say, how he collected data, we're talking about the adventures he had along the way.

The next question we have is: **What is the clutch size?** Remember, rocs only lay one clutch in a lifetime. Again, we have information from Sinbad the Sailor. He did a survey of nests. I don't know how many nests he surveyed, but the number he came up with is 1.06 for the average clutch size. So we have 703 rocs now, and the average clutch size is 1.06.

The next question is: **How many of the eggs actually hatch?** That one is easy to answer. They all hatch.

Then we have a question about chick survival. **Do they survive to fledgling stage?** And the answer here is that they all survive to fledgling stage provided there is a sailor in the nest. If there's no sailor in the nest, the chicks die. Simple as that.

Next question goes onto adult survival. **Do all rocs live to 100, at which point they self-destruct?** The answer is yes unless they get hit by a silver bullet. Oh, I haven't mentioned silver bullets before. Well, if you've been around the docks, you will noticed that really rich captains wear a silver chain around their necks with a bullet hanging at the edge of the chain. That is a silver bullet that is capable of killing rocs. It is very difficult to produce a silver bullet capable of killing a roc. You are required to say the right incantations at exactly the right moment. If you had garlic for supper the night before, it doesn't count. You have to start again. If the clouds move over the moon while you're making a certain mixture, you have to throw it out and start again. Our best estimate is that something like 20 silver bullets are produced per century. These are highly prized, and only the most affluent captains can afford them. So we

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have 10 to 20 bullets produced per century. We don't know how many of them are actually used. To make it slightly more complicated, there are rumors that in the back streets of the market in Baghdad you can find black market silver bullets. The gild of silver bullet makers warn sailors that black market silver bullets probably don't work. And to the best of our knowledge, only about another 10 to 20 are produced anyway, for the black market.

The next question is: **Are there any other mortality factors?** Predators, disease or anything like that on adults? And the answer to that is none that we know of.

Somebody's asked about the **age structure of the present population**. That's a really good question, but we have absolutely no information.

There's a question **about nesting sites**. Rocs nest on the tops of mountains. Again, Sinbad the Sailor did a very careful survey of all mountains in Arabia and came up with a figure of 4,000 possible nesting sites in the whole of Arabia.

Next question says: **Are there any food limitations for rocs?** Well, adult rocs eat elephants, and there really is no shortage elephants and never likely to be a shortage of elephants. They don't eat many, one or two per lifetime. Sailors might be a limitation, but again, if you do a quick calculation, you've got 700 rocs. They need one sailor every hundred years. You're looking at about seven sailors per year. I'm sure you'll always be able to find seven sailors per year around Saudi Arabia.

And finally, there's a question about population history. **Do we know anything about what happened to rocs in the past? Do we see population trends?** And the answer to that is, unfortunately, no. Nobody ever thought to monitor rocs until the caliph became interested a few days ago.

[Next Task]

Let me tell you what your next task is going to be, because it's changed a little bit. Last night Scheherazade was, as per usual, reading to the caliph, and she chose to read to him out of PC Magazine, and the latest issue of PC Magazine mentioned spreadsheets, and in particular Excel. And, the caliph decided he really likes spreadsheets, and so the model you're going to develop is going to run on a spreadsheet.

So your next task is to take the information that I've given you - design your model world, figure out what you are going to put on and into a spreadsheet, where you are going to start with the current population of rocs, and where you're going to end up with the population a thousand years from now. So you really are going to have to go and design your model and think about how you would put it on a spreadsheet.

Using a spreadsheet is actually going to make your job a little bit easier. Think about a spreadsheet on the computer. Imagine that you've got two columns on the spreadsheet. The one column says year, and it will start in the year 1000, and then it will go down in increments to the year 2000. And the other column will say rocs, and it's going to start off with 703 rocs. And, basically what you need to do is figure out a formula that takes you from that 703 rocs step by step through to the year 2000.

So there are really two decisions you have to make in your next breakout session. The one is **what is your time step?** Are you going to go from the year 1000 to 1001, 1002, 1003? Or are you going to go in 10-year increments? Or one-day increments? You decide. And then once you've chosen that increment, **what formula takes you from current time to next time?** You're going to have to have a way of calculating - if I know the roc now, how many rocs are there going to be at the next time step?

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