

Old bones and modern germs

Nancy: It's the year 1200 in Trondheim, Norway, and a young woman is walking the streets of this bustling little city on the coast of central Norway. Although it's far from mainland Europe, it's an important ecclesiastical center and a prosperous place, with perhaps 3000 inhabitants or more. The Archbishop, the see of Nidaros, is rich and powerful, and trades in treasures from the far north — walrus tusks, dried cod and furs.

Nancy: But this young woman — let's call her Ragna — probably isn't thinking much about that. Instead, she's probably thinking about how really rotten she feels. She's got a fever and chills. Her abdomen hurts — not in one place, but everywhere.

Nancy: Ragna, researchers have figured out, has a disease that no one thought was found in Europe in the Middle Ages.

Tom Gilbert: a pathogen called *Salmonella enterica*. And in particular, something called the Para C lineage...this pathogen that we essentially thought, it's not really a thing in Europe, it was running around 800 years ago, clearly causing a lot of damage, probably killing people.

Nancy: It would be another 150 years before the dreaded Black Death arrived on Norwegian shores, yet here was another potent killer prowling mediaeval Trondheim. You'd think there would be a trace in the written records of the time. But there isn't.

What's even more surprising about this particular pathogen is how researchers were able to identify it in Ragna's 800-year-old skeleton.

Because they found their evidence... between her teeth.

Nancy: I'm Nancy Bazilchuk, and you're listening to *63 Degrees North*, an original podcast from NTNU, the Norwegian University of Science and Technology.

Today I'm going to tell you the story of how researchers are fishing out fascinating stories from places like Trondheim's mediaeval cemeteries, latrine wastes and dental plaque — and how they're using information from these unlikely sources to see how diseases changed the way mediaeval populations behaved — and how they can help us understand how pandemics like SARS-CoV-2 happen, so we can better combat pandemics in the future.

Nancy: The backbone of this entire story is what happens when mediaeval Trondheim meets modern technology. It turns out there's more to Ragna and other 800 year old skeletons than what lies between their teeth.

So let's begin at the beginning — of Trondheim, that is.

Axel: Trondheim... it, was, and still is a town on the outskirts of Europe. It's sort of Ultima Thule.

Nancy: Ultima Thule, the Latin phrase that means, essentially, distant place located beyond the "borders of the known world." And our guide to this distant place is...

Axel: Axel Christophersen and I am a professor in historical archaeology at the Institute of Archaeology and Cultural History at the Science Museum.

Nancy: Back in 2016, Axel got interested in the medical archaeology of Trondheim, and not just because it happens to be the town where the University Museum, where he works, is located.

Axel: We had really good archaeological sources from this time, because there has been a lot of professional archaeological excavations in this town from the beginning of the 1970s and the conditions for preserving organic material and skeletons are superb.

Nancy: Axel and his colleagues decided they wanted to look at a broad swath of time, all the way back to the year 1000 and up to 1600, which is more or less the beginning of modern times. It also includes the period in the 1300s when all of Europe was devastated by the Black Death.

So there's a lot going on if you are interested how diseases affected mediaeval populations. And plus, the practice of archaeology, like many other scientific endeavours, has really been revolutionized by our ability to study DNA and other secrets hidden in human bodies.

So let's step back in time, to see what it was like back in the year 1000, about 200 years before Ragna walked around in this little town on one of Norway's largest fjords.

Axel: Trondheim is located on a peninsula close to the estuary of the river Nid. And it originally is from a small trading place which was established around 900. In the second half of the 900s, it became a regional trading place, a kaupang we call them.

....

Axel: it was a condensed population around the little bay, consisting of around 250 people but it expanded rapidly through the 11th and 12th century.

So, when we are at its peak around 1300, there's nearly 4,000 people living in this and that is an average, big city ...compared with other Nordic towns around 1300, one of the biggest cities in Scandinavia at that time.

Nancy: So 800 years ago, when Ragna lived here, there were likely several thousand people living in Trondheim. And as Axel said, it was a regional trading place, with lots of people coming from all over northern Europe, converging on the city.

Axel: But compared to north European standard, it was very little. Paris had 20,000 and also London. So it was little, but within this Nordic hemisphere it was quite big, because it was a quite rapid population expansion during the 11th and 12th century.

Nancy: About that population expansion? It turns out that Ragna also had a second secret preserved for eternity in her bones.

Nancy: Remember Axel said that one reason they decided to do a deep dive into mediaeval Trondheim was because of all the well-preserved skeletons? It turns out these skeletons have lots of stories to tell, not just from their DNA, but because of something called isotopes.

Nancy: This is a little complicated, so stay with me. Isotopes are variants of elements that are found in small quantities. Most people have heard of Carbon 14 dating. Carbon 14 is a variant of carbon that can be used to date organic material. But other chemical isotopes can tell biologists and archaeologists where you lived at certain periods of your life, in part based on what you eat or the water you drank. Tom Gilbert, a professor at NTNU's University Museum and head of the Center for Evolutionary Genomics at the University of Copenhagen, who we heard at the top of the podcast, explains.

Tom Gilbert: So your bone changes through time. If you take a bit of your femur and look at the isotopes, it will give you where you've been the last few, four or five years, if you take your hair it will be the last few weeks or months. Enamel is where you were a kid, where you lived when your teeth are developing.

Tom Gilbert: Trondheim has a remarkable skeletal collection from all collected around the town, dating back about 1000 years. And we've actually been studying what pathogens are in the samples. What that might tell us about the past.

Nancy: Like Ragna, whose skeleton was excavated from what archaeologists have identified as the medieval ruins of St. Olav's Church cemetery. She and many other

skeletons were found here during a 12-year-long archaeological dig that started in 1973. The main public library, in the town's center, was subsequently built on this site. You can even see some of graveyard's remains, including skeletons, preserved in the library's lowest level.

Tom Gilbert: And her isotopic signal, actually, ... is consistent with either very North Norway or actually Greenland or possibly Iceland. So it suggests she was some degree of a migrant. I mean, genetically she's a Viking but Vikings were all over these regions. So she didn't actually grow up in Trondheim at the early age. And yes, she could have come from any of these regions.

Nancy: Vikings!

Nancy: And it turns out that Ragna's disease tells us something else about what it was like in Trondheim at that time.

Tom Gilbert: Given that this sequence has got the very special form, we can actually guess it actually looks like it probably did in Europe originally, possibly actually, through a contact with pigs. We had various evidence that point to that, so it might be one of these pathogens that arises once humans start basically domesticating animals and living too close with pigs, and then these pathogens can jump across to humans and start things.

Nancy: Hmm, perhaps Ragna could have gotten her disease through contact with pigs? Yet the research Axel and his colleagues have done suggests the city itself wasn't quite as filthy as it's portrayed by Hollywood.

Axel: People, they have their thoughts of the Middle Ages from Monty Python, or the Vikings or Game of Thrones. And in these fictionalised series, the environment is not correctly shown. It was cleaner, that's one thing.

Nancy: Axel says animals wastes and food scraps and the like weren't just tossed out into the streets. Instead, people were really deliberate with how they used these materials. And they used these wastes to...

Axel: to level the surface for buildings and for streets, because sand and gravel, you couldn't get that everywhere. From the second half of the 11th century, it seems that they started to care more about the physical environment.

Nancy: And part of the way we know this is because of how they handled their water. There's one whole PhD candidate working on this issue.

Elisabeth: My name is Elisabeth Forrestad Svensen, and I am a PhD candidate at the NTNU University Museum. And currently I'm working on the mediaeval archaeology, looking at what is called water and waste management, in Trondheim, in the mediaeval, and also early modern age.

Nancy: Elisabeth is doing a lot of digging, but not in the way you might think.

Elisabeth: When I'm working, I wish I could say I was digging, but I'm not. I'm more like a documentation archaeologist at the moment. So I'm looking at the old excavations, the excavations that has already been done. So I'm looking at excavations from 1928, from 1937, from 1945. And also from the 1970s. And for also the 1990s. I'm kind of digging into the documentation.

Nancy: Think of Elisabeth as a sleuth who's totally passionate about figuring out what all the little clues in the documents from the old excavations can tell her.

Elisabeth: Archaeology in itself, it's very interesting because you kind of get a different view of the history that's not in the history books. ... it's something that's not been in the light before, it's the remains that no one actually intended to be found. No, it's kind of the secret of the people of the past. Yeah. But even though it's not, it's not secrets, because it's their daily life. It's the normal things, how they ate, how they walked, how they built their houses. It's the normal things. It's not the elite stuff, that much, it's, yeah, it's the common man, the common woman, the common child.

Nancy: And when she's digging into the documentation, Elisabeth is paying close attention to the maps that the archaeologists of the past drew, as they slowly and painstakingly removed layer after layer of dirt, looking for discolorations in the soil, or pieces of wood that seem deliberately placed.

Nancy: By using powerful computer mapping programs to combine all this information from the five different periods of excavation in Trondheim and literally thousands of observations, Elisabeth can begin to see patterns.

Elisabeth: And what I have done actually, is to use this drawings that are now in PDF files. And I have put them into this map programme ArcMap. And I have geo referenced them in real time so I can see exactly where they are in Trondheim now.

Nancy: Elisabeth says the oldest drawings are extremely detailed, because archaeologists at that time used drawings, rather than photographs, to precisely record what they saw.

Elisabeth: From this oldest excavations, the drawings are the most important; the drawings of wells, the drawings of drainage ditches, drawings of latrines. They kind

of mapped it in a spatial map, like they draw the outer edge of their excavation, and then they're neatly drawn small parts of the wood. Also, they could have detailed drawings of one specific piece of wood, how it was cut, it was so nicely done really, really nice.

Nancy: So why do we care about where old drainage ditches and latrines were placed in mediaeval Trondheim?

Nancy: It may seem trivial, but it's not, this question of what townspeople did for drinking water, but also with their wastewater.

Because that disease that Ragna had, it's mainly spread by animal faeces, or to use the technical term, poop. Someone living in a mediaeval town, if they wanted to stay healthy, they had to make sure that they could drain any water contaminated by their wastes away from wherever they got their drinking water.

Nancy: That means mapping where and when drainage ditches, wells and cisterns were constructed related to mediaeval streets and houses helps Elisabeth and her colleagues figure out...

Elisabeth: ...what kind of water and waste management can we trace in the mediaeval and early modern environment? ...Is there a change in the public from private to public responsibility? And does this relate to developing a sense of health? And how to manage health and is this visible in the management of water and waste management?

Nancy: It's still early in Elisabeth's research, but a few things are beginning to come clear. One thing is that drinking water was a challenge, even though the settlement was on a river in a place where water is plentiful.

As she looks at her compilation of drainage ditches, water wells and latrines, it's clear from their placement that the wells could be contaminated, either by dirty runoff, whether wash water or water from a latrine. And because Trondheim is right on the fjord, if mediaeval residents dug their wells deep enough, the sea water from the nearby fjord would seep into the bottom of the well and make it undrinkable.

Nancy: At the same time, there's the Black Death, which arrived in Norway in 1349. So whatever plans townspeople might have had to improve their water situation were likely put on hold, at least for a bit. The Black Death affected everything. Tom Gilbert says he and his colleagues were able to study the genetics of roughly 200 people from this period.

Tom: We can say very clearly right now there was a big demographic change in Trondheim, because in addition to what genes there are, you can actually assign

population origin. And so we can see before the plague comes in before like 1349, or whatever, there's a lot of mobility to Trondheim, we can see lots of genes in the people derived in particular from the British Isles, which fits with the Vikings came backward and forward.

Nancy: Yup, those Vikings liked to wander!

Tom Gilbert: So we see a lot of mobility to Trondheim before 1347. After? Nothing, there's no mobility coming in, they look like very, very modern, very, very local Trondheimers, so you can actually see in the genetics that goes from this cosmopolitan place where people are coming out to essentially a backwater of little importance which is documented by the in the history, it is the capital and then it's not the capital, it's the center of the walrus ivory trade, and then it isn't, right.

Tom Gilbert: So the fact you see it so striking in the genetics around the time of the plague, it goes from all this gene flow coming into nothing. It's kind of kind of cool. And that, again, actually has pathogen implications because the more people coming in, the more pathogens you're bringing in. And actually, if you're just a dead backwater, bringing in the local pathogens, it's another thing. So you can actually see some quite fascinating things in the human population from the results.

Nancy: The Black Death also clearly affected the way that people — and town authorities — took responsibility for public health. And here's one more example of how the archaeological findings help support what historians know of the time.

Axel:

After the, the great plague they knew that they had to keep distance, they had to improve the physical environment.

Nancy: And we thought social distancing was a relatively new phenomenon!

Axel: But still there was this religious mentality that says that “You are sick because you had done something wrong and God will punish you”. So what they did during the middle ages was to pray commonly to God outside or inside the churches to please God. And to say that we are sorry for being bad people. During the plague in the 14th century, there was people, who punished themselves. It was to say to God that we want to be good people to please him. And this was quite common, but it didn't work. They saw that. We could pray to God and we could be as good people as we could, but even good people died from plague and various other diseases.

Nancy: And the result?

Axel: So, ... they started to mistrust the religious authorities. They gradually changed mentality from being directed by religious rules to take more knowledge from their own worldly experiences. This experience told people that we need to have a clean environment. And they improved the laws so that people were forced to do things that improved their own cleanliness, and the environmental cleanliness.

Nancy: So what did town leaders do?

Axel: Plot owners, they were legally forced to brew beer. Of course, because when they brew beer, they disinfected the water. So this was indirectly a way to improve the water. So the urban towns authorities, they made it possible for all people to have access to something to drink.

Nancy: But what's even more interesting is that town authorities avoided the ultimate responsibility for providing clean drinking water for residents for more than a century! Instead, residents had to walk roughly 2 kilometers to get fresh, clean water from a little creek called Ila Bekken. And some of the cisterns that Elisabeth has documented were almost certainly used to collect rainwater, since the wells weren't safe to drink.

Axel: In the early 1600s, they knew that they had to act collectively, and they knew that they had to even improve the water technology. So in Trondheim they tried to convince the town authorities to build a piped water line from those earlier source of water sources outside —that didn't happen until 1777.

Axel: So that is another interesting thing that all during the Middle Ages, they, they changed mentality from health being purely in the individual responsibility to a sort of bio political activity. But due to political and economic reasons, they couldn't realize the plans they had for over a hundred years in improving the water, which was absolutely the essential thing for having better health.

Nancy: Even though they knew they had to act, and what they had to do to make things better, they didn't do anything. Sounds a little bit like how societies are now dealing — or not — with climate change. Maybe we're not so advanced as we think we are.

Nancy: And what of Ragna? Another thing researchers could tell from her skeleton is that she died relatively young, between the ages of 19 and 24. And while her skeleton is the only one to date where the researchers found the salmonella pathogen...

Tom: The fact that we find it at all suggests it was very common, because you only find remains of the very, very common things. This is a probability game, the rarer

something is, the even more unlikely you will ever find it, once you factor in all the skeletons that have been lost, and so on....it tells us that there's a much wider range of pathogens than we might imagine in Trondheim in the past killing people.

Nancy: So we know about the Black Death because people died in droves and people wrote about it. The Black Death sent European societies nearly back to the Stone Age.

But here's a pathogen that's not supposed to be in Europe at all, killing people. It's of academic interest, of course. But think about the pandemic we're in right now. Could we have seen SARS-CoV-2 coming? Can learning about these ancient pathogens help? Tom Gilbert says yes.

Tom Gilbert: By getting the old pathogens one can study when this transmission happened, what kind of characteristics are needed, which again, can then be translated back into the useful information for monitoring today.

Tom Gilbert: So it's about extra knowledge where do things come from, how do they adapt? How easy is it for pathogens to jump?

Nancy: That's a question we're all learning to care about more, given the coronavirus pandemic. And that brings us back again to Ragna. Eight hundred years ago, she trod the wood-paved streets of Trondheim, unaware that the pain in her stomach was the beginning of her end. When she died and was buried in the St. Olav's Church graveyard, she took the riddle of her death with her, to be deciphered by researchers nearly a thousand years into the future. Ragna, the name the researchers gave to her, is actually an old Norse name that means "advice". It raises the question of what kinds of secrets — or potential advice — still lie hidden in these skeletons from centuries ago.

Nancy: I'm Nancy Bazilchuk, and you've been listening to 63 Degrees North, an original podcast by the Norwegian University of Science and Technology. Editorial help and sound design by Historiebruket. Thanks for listening.