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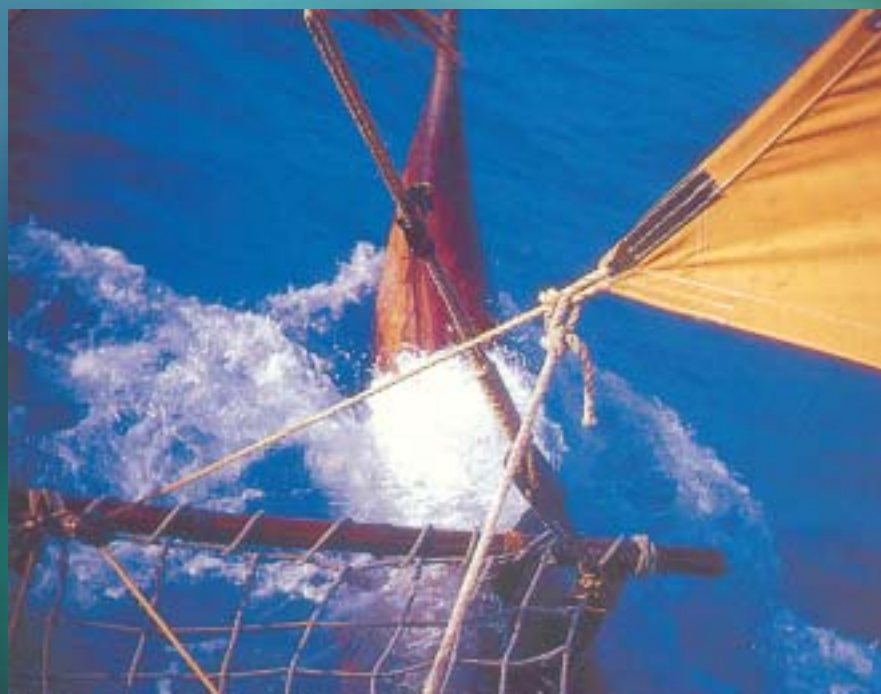
Unravelling the links

mitochondria & Maori migrations



The Royal Society of New Zealand

Using DNA technology to understand the Polynesian founding of Aotearoa New Zealand

In an unexpected and fascinating new application of biotechnology, DNA sequencing is being used to solve problems in the field of anthropology and social history. Tiny fragments of DNA taken from the mitochondria of present-day Maori and Polynesian volunteers have recently produced evidence to support the planned migration of the first Maori to Aotearoa New Zealand.

Origins of the Pacific people

Anthropologists generally agree that between 2000 and 4000 years ago the islands of the Western Pacific were first colonised by a pottery-making people from South East Asia (probably from Taiwan). This theory has been supported by archaeological findings as well as modern research into **linguistics** (the study of languages), the genetics and origins of food plants, and human DNA studies.

from *Waka – Application Series*

These newcomers to the Pacific had earlier colonised parts of Melanesia (New Guinea, the Solomon Islands, Vanuatu, New Caledonia and Fiji) and also Micronesia. Because remnants of their distinctive, patterned pottery were first found in Lapita in New Caledonia, these early Pacific settlers have since become known by anthropologists as **the Lapita People** (Kirch 1997).

The Lapita were the ancestors of the Polynesians, and it was from the islands of Fiji, Tonga and Samoa that their descendants set out on great migratory voyages. Gradually, they settled nearly every habitable island in the vast triangle of the ocean we now call Polynesia – including Aotearoa New Zealand.

The Lapita People were inventive and artistic. They developed huge, strong, double-hulled canoes and a sailing technology which enabled them to tack against the wind. Their vessels, called **waka**, had one or two double-boomed, triangular sails. The great strength of these boats was critical for survival on long journeys, and the ability of their sailors to tack permitted the deliberate two-way voyaging which was necessary for the discovery and later settlement of the far-flung islands of Polynesia.

The Polynesian exploration and settlement of the Pacific is one of the most remarkable achievements in human history. Many long epic journeys were made across vast reaches of open ocean, and new islands were discovered. Navigational skills had to be refined and more highly developed to become powerful and successful aids to these explorers.

It seems that the Polynesians steered on courses set by the position of the Sun and stars. Their knowledge of the different constellations and their movement through the heavens had much of the sophistication of the early Greek astronomers. Their language was rich with the names of stars such as Tawera (the Morning Star), Matariki (the constellation of Pleides), Tautoru (Orion's Belt), Atutahi (Canopus), Te Ika-roa (The Milky Way) and numerous other features of the night sky.

Did the founding of Aotearoa New Zealand involve planned or accidental arrivals from the Pacific?

The settlement of Aotearoa New Zealand, occurring around 800 years ago, appears to have been the most recent and most difficult stage of this remarkable Pacific migration sequence. Polynesian ancestors of the Maori, in exploring further south, would have had to cope with longer distances between land than in the mid-Pacific, and weather patterns and sea conditions which were more hazardous (and much colder).

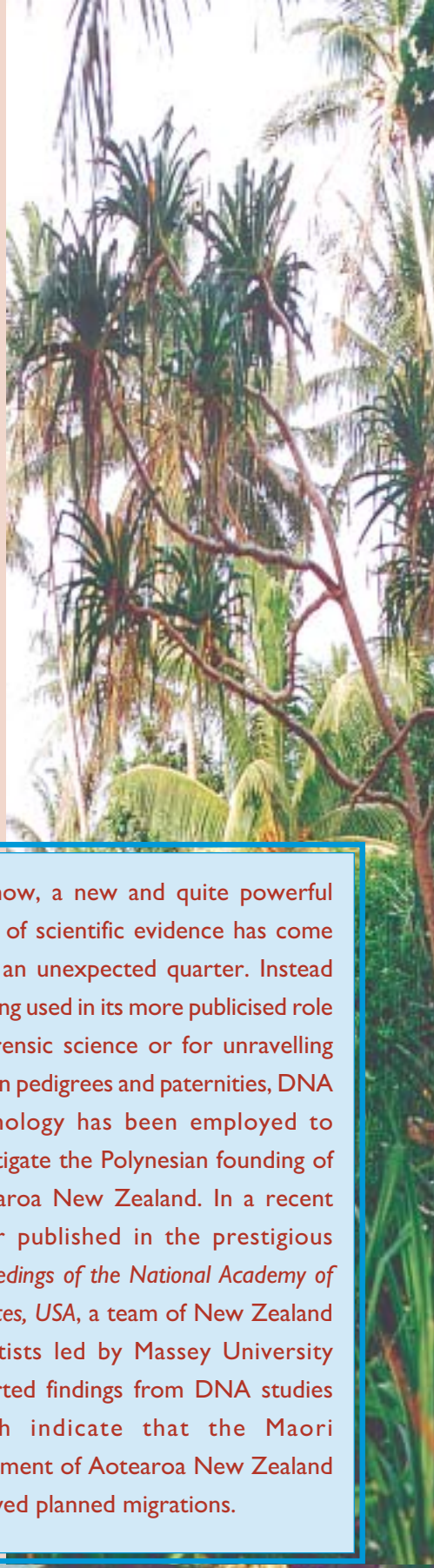
Some historians have argued that, because of these physical difficulties and the relatively simple boat building methods and navigational skills of the time, Aotearoa New Zealand must have been settled accidentally, with only a few canoes being blown randomly or even drifting to our shores.

The chance settlement of Aotearoa does not, however, fit with oral histories of this period. In Maori stories and songs that recount the voyages and eventual colonisation of Aotearoa New Zealand by their ancestors, there is a wealth of information about a surprising number of waka which travelled here. Instead of their arrival being accidental, the Polynesian forebears of the Maori people are credited with embarking on deliberate reconnaissance voyages to find new settling places, and of a significant number of return journeys and a two-way traffic of waka between Aotearoa and the homelands.

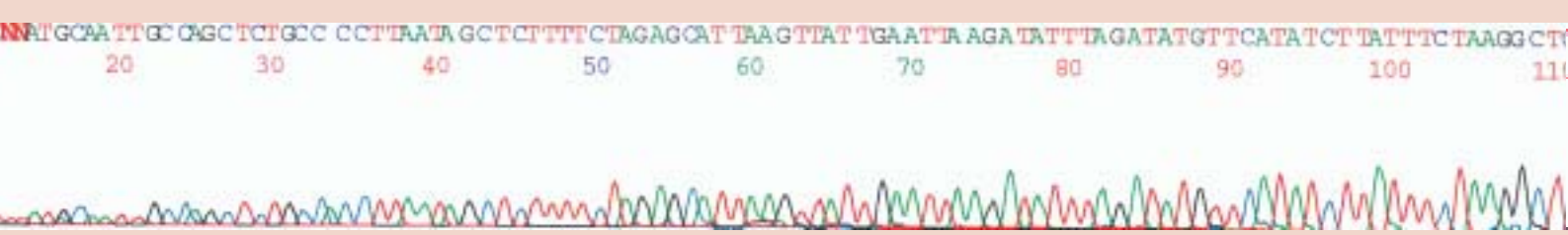
Archaeological findings are also consistent with the view that many waka came and they came deliberately. Computer-simulated voyages, which have incorporated actual drift patterns and information about prevailing weather systems, also tend to discount the drift theory. Tacking against the wind must have been employed, and negotiation through complex weather systems must have been both skilful and intentional.

Convincing evidence has also come from the experiences of modern canoe expeditions which have set out to recreate early trans-oceanic voyages down through the South Pacific. Using only traditional Polynesian methods to build and navigate replicas of the great waka, New Zealanders Francis Cohen and Matahi Brightwell (with the *Hawaiki-nui* in 1985), and Hekenukumai (Hec) Busby (with *Te Aurere* in the 1990s) have shown that planned migratory voyages south from the Pacific Islands were entirely feasible. The navigational techniques of the Hawaiians were also tested successfully as far back as the 1970s with the journey of *Hokule'a*.

While quite varied information about the origins of the Maori people accumulates, lively controversy continues. Over recent years, contemporary academics from a variety of disciplines have been drawn into the debate. Margaret Orbell and David Simmons, for example, suggested that many of the waka traditions handed down over the centuries were memories of voyages that were made by ancestors along the shores of Aotearoa and not voyages made directly from the Pacific Islands.



But now, a new and quite powerful piece of scientific evidence has come from an unexpected quarter. Instead of being used in its more publicised role in forensic science or for unravelling human pedigrees and paternities, DNA technology has been employed to investigate the Polynesian founding of Aotearoa New Zealand. In a recent paper published in the prestigious *Proceedings of the National Academy of Sciences, USA*, a team of New Zealand scientists led by Massey University reported findings from DNA studies which indicate that the Maori settlement of Aotearoa New Zealand involved planned migrations.



David Penny organised the computer calculations that estimated the number of Maori mothers that arrived in Aotearoa New Zealand.

These researchers examined nucleotide base sequences from mitochondria DNA (a tiny fragment of human DNA that is only inherited from mothers) extracted from the cells of Maori and Polynesian volunteers. They also carried out over a million computer simulations in a series of statistical calculations designed to model the steps involved in the founding processes of Polynesian settlement of the Pacific.

Findings from the Massey study led to the conclusion that a minimum number of between 50 and 100 Polynesian women were needed for the founding female population of Aotearoa New Zealand – a number too large to be accounted for by the haphazard drifting or storm-blown arrival of wakas reaching our shores accidentally. These findings are consistent with a general understanding of Maori oral history which describes the arrival of at least 8–10 waka with an estimated 5–10 women per canoe. The results are therefore consistent with deliberate Polynesian exploration and settlement of Pacific Islands.

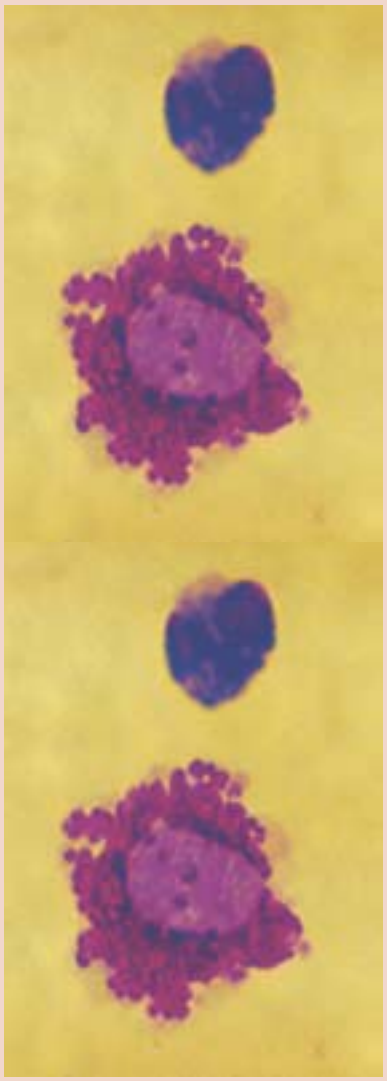
Why use mitochondrial DNA rather than nuclear DNA?

Mitochondria are tiny structures or **organelles** found in all cells of our bodies. They are the "powerhouses" of our cells, producing energy from the food that we eat. To do this, mitochondria need a supply of oxygen, and the process involves a complex, step-wise, biochemical sequence which occurs on the folded inner membranes of the mitochondria. We call this process **cellular respiration** and it is vital to produce the energy necessary for metabolic processes in living organisms.

Mitochondria are very unusual cell organelles because they are equipped with their own DNA. This DNA forms a circular loop and lacks proteins called histones. It is, therefore, rather like the DNA we find in prokaryotes**.** (Remember that organisms can be divided into two broad groups – the **prokaryotes** (bacteria) and the **eukaryotes** (all other forms of life).)

The fact that the DNA of mitochondria is like that of prokaryotes is not surprising since these organelles are thought to have evolved from early prokaryotes that gained entry to the cytoplasm of ancestral eukaryotes and then set up a permanent **symbiotic** (living together) relationship with them.

In humans, mitochondrial DNA is only about 16 380 nucleotides long. This is very much shorter than the DNA of the nucleus, which is nearly 200 000 times longer. It is believed that most mitochondrial DNA was eventually assimilated into the nucleus but



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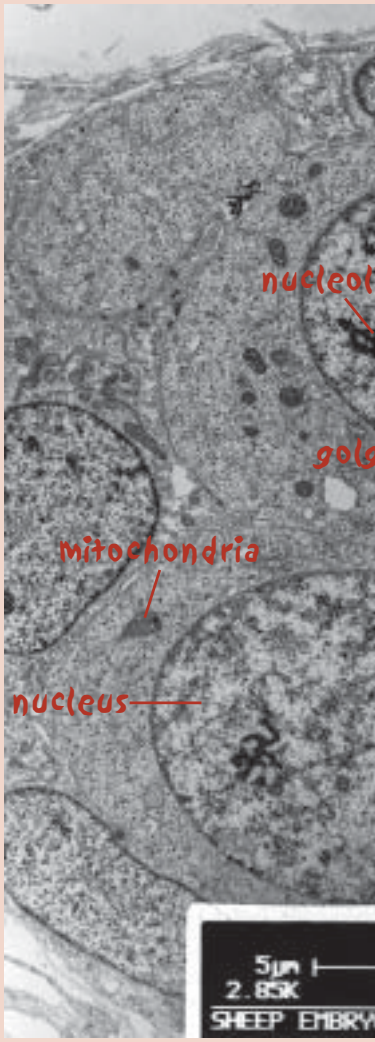

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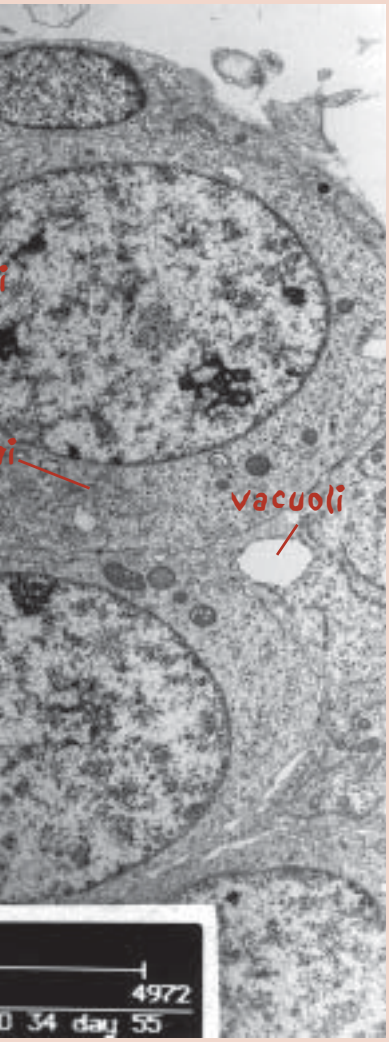
the remaining quota that persists even today in the mitochondria themselves has rather interesting characteristics.

There are differences between the DNA of different individuals, especially in the "non-coding" regions of nuclear DNA. However, in vertebrate animals, including humans, mitochondrial DNA (**mtDNA** for short) has a faster rate of mutation than any other human DNA.

Over the last half million years or so, it has changed enough to allow historical relationships between groups of people and their migrations to be traced. By examining **mitochondrial** rather than **nuclear** DNA, differences between people are much more evident.

To further enhance the possibility of locating detectable variations in DNA, specific regions of mtDNA are frequently chosen for DNA sequencing studies. These regions are called **hypervariable regions** because they exhibit more genetic variation than other zones of the human genome. The regions of the DNA desired for sequencing are amplified by the method of polymerase chain reaction (PCR) using primers which are small sequences of DNA that bind to the chosen section of DNA.

In the study of genetic variability of Polynesian and Maori volunteers conducted by scientists, a hypervariable region of mtDNA (known as hypervariable region 1) was used for DNA sequencing, and mtDNA produced more resolution of Maori and Polynesian origins than could have been produced with studies of nuclear DNA.

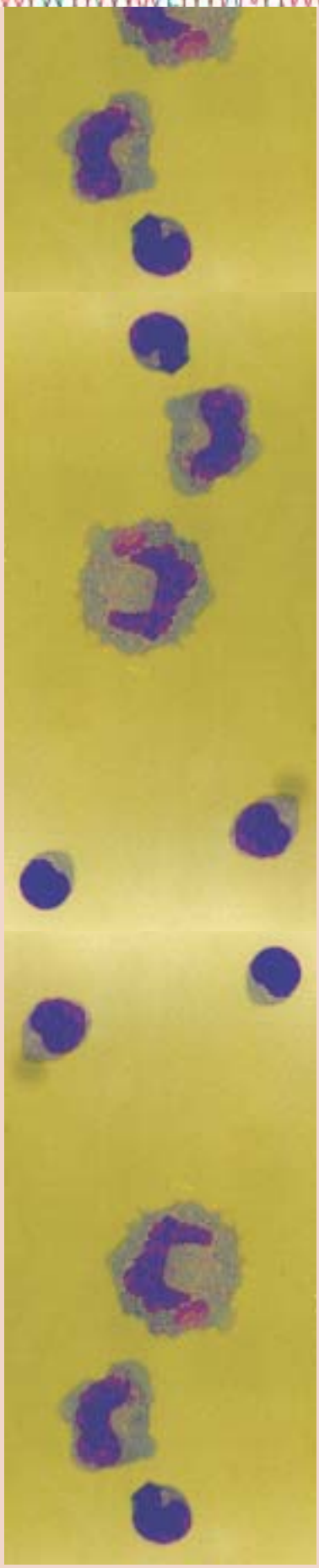


OL OF MEDICINE & PETER SMITH, AGRESEARCH.

Why does this study give us information only about women settlers?

Although both men and women have mitochondria in their cells, the mitochondrial **genome** (or complement of genetic material) is passed only from mother to child. The mtDNA that one inherits comes from one's mother. This means that studies examining mtDNA only (in order to see genetic variation more easily) gain information about female descent.

Additional studies using Y-chromosomes could be used to estimate the number of Polynesian men contributing to the New Zealand population. As the Y-chromosome (along with other nuclear DNA) has much less variability than mtDNA, more segments of the DNA need to be sequenced to reveal differences between individuals or groups. Several teams of scientists are presently working to achieve this for overseas populations.



Sheep gut mucosal cells. AGRESEARCH

What did examination of mtDNA reveal?

For the new DNA study, New Zealand volunteers with an unbroken line of Maori mothers donated strands of hair or a little blood at the same time as blood being given for other purposes. They described their mothers' **iwi** (family lineage and affiliations) to ensure that the sample studied was representative of the Maori population. The sequences of part of the mtDNA obtained were analysed in conjunction with results from other Maori sequences previously published by other researchers.

Though a particularly variable region of human mtDNA was chosen for the study, sequences from New Zealand Maori volunteers showed much less variation than other Polynesian groups used in the investigation. Altogether there were only four variants, or **haplotypes**, in the DNA sequenced from the 54 Maori volunteers. None of these were new mitochondrial sequences – all of them had been reported by other researchers working on Polynesian DNA. This observed mtDNA variability proved to be one of the lowest of any sizeable human group that has been studied so far.

The Maori and other Polynesian mtDNA sequences examined in the study were also compared to 268 published sequences from other studies of DNA from contemporary Pacific people. Results from this particular phase of the study indicate that variability in mtDNA is reduced in Polynesians compared to other peoples and that this variability decreases from western to eastern Polynesia.

These findings are consistent with a series of **founder effects** in small populations dispersing eastward, stage by stage, to settle new island groups across the Pacific. This means that, in each new colonisation move, only a portion of the parent population left the homeland. Step by step, the number of available genes (and hence variations in them) would be reduced in the migrating population. The founding population of any new area took with them a genetic complement that was only part of the original gene pool of the parent population.

The Massey study was therefore able to find genetic evidence for this decreasing west to east genetic variability, a finding that is consistent with our understanding of step-wise Polynesian colonisation of the Pacific. It is also consistent with Aotearoa New Zealand being the last region to be settled and hence with the smallest number of haplotypes in the founding population.

Catamaran *Te Aurere.* *with permission of Mr Hekenukumai Busby, Mangonui.*

How was the number of female ancestors estimated?

Using statistical methods and computer simulations, the Massey teams were able to estimate a minimum range of between 50 and 100 women who would have been necessary to produce just the **four DNA variations** (the haplotypes) which were found in the set of volunteers. Altogether, well over one million simulations were performed to substantiate the conclusion. The three-step simulations were built around a model in which

- a selected founding population arrived from Polynesia,
- an expanding phase occurred in Aotearoa New Zealand, and finally
- only a sample of the overall Maori population of Aotearoa New Zealand was selected for the assessment of haplotype numbers.

In all of the calculations it was assumed that the different variants (haplotypes) were equally functional and none conferred a health or other advantage or disadvantage. A discovery of modern molecular genetics is

that most variants at the DNA level function equally well. Groups of people sharing a particular DNA variant therefore cannot be said to be genetically "better off" or "worse off" than others. We can consider different DNA haplotypes as useful markers to help understand origins and migration. Earlier fears of genetic data being used as a basis for making value judgements about ethnic groups need no longer hinder science's uncovering of the histories of people.

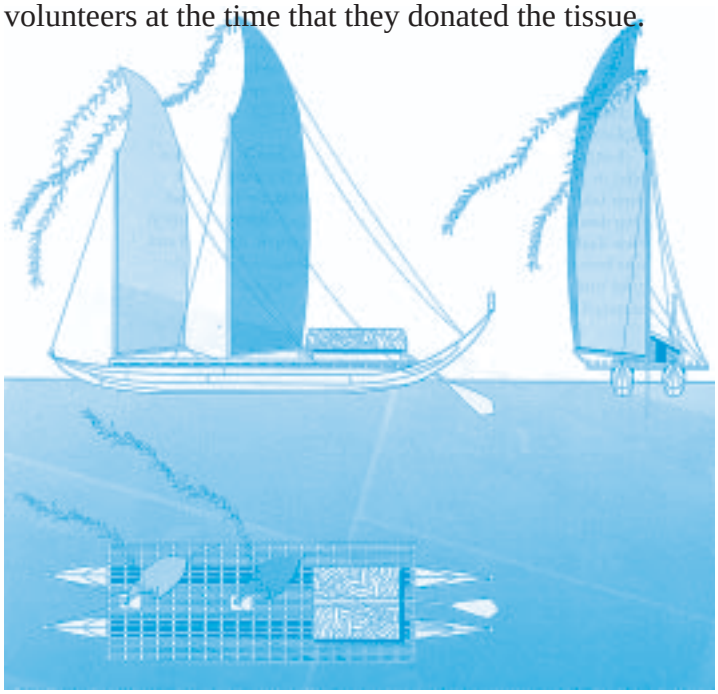
Of course, some DNA variants do not function well. A small number are associated with tendencies towards disease, and medical research is addressing identification of these variants and ways to ameliorate or circumvent health problems associated with them. These variants are rare, are often spread quite widely around a region and are not confined to a local ethnic group. Most DNA variants are not associated with any tendency to disease – they appear as random variations. There are no markers or variants associated with disease that are specific to any group of people. Rather, there are gradients of gene frequencies across large regions of the world. The idea of pure genetic races which was used in the past as an apparent justification for gross social inequities and even war, has been made untenable by molecular genetics.

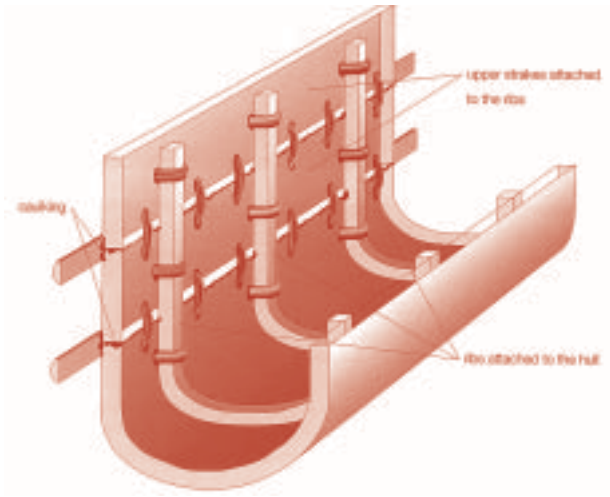
Associate Professor Rosalind Murray-McIntosh, one of the principal researchers in the Massey study, reported that the co-operation of the Maori volunteers in the project was most rewarding. She explained that those who took part in the study were very interested in the project and its outcome. They were keen to participate and to share their impressive knowledge of their whakapapa (family histories) and researchers "felt privileged to have been able to contribute confirmatory information about the founding of Aotearoa New Zealand from a different, genetic perspective".

Other benefits that will emerge from the study of DNA sequences

Differences in sequences in other parts of human DNA are being found by researchers worldwide. From these, it has sometimes been possible to determine genetic susceptibility or non-susceptibility to a wide range of health problems, many of which appear in Aotearoa New Zealand. In many cases, individual lifestyle or treatment programmes can be designed to cure or improve the health of those individuals found through study of DNA to be predisposed to a particular disease. Health advantages may then become increasingly available to all ethnic groups in Aotearoa New Zealand, including Maori. As more genes are studied, this type of programme will be enhanced.

It is important to recognise that researchers in Aotearoa New Zealand are not able to use tissue for any studies that were not fully described to the volunteers at the time that they donated the tissue.





Double-hulled waka – plans and lashing details. from *Waka – Application Series*

Mitochondria and migrations – a final perspective

Our models for migration from west to east across the Pacific are borne out by the findings of this new and exciting DNA study. As well, it appears that the genetic evidence also points away from chance settlement. To account for the observed genetic variation, too many female ancestors are required for them to have arrived here by chance. Unless waka set out with females on board, deliberately bound for new lands, very few women would have reached the South Pacific. Usually, war canoes or those just exploring for new land did not risk taking women with them. Oral histories record groups of warriors or male explorers setting out alone for these purposes.

The present study estimates that between 50 and 100 females is the least number of Polynesians that must have come originally to Aotearoa New Zealand. This is in remarkable agreement with the tradition that reports 8–10 waka, with probably 5–10 females per canoe. Also, the findings do not contradict the concept of a much greater number of waka arriving collectively or in small groups over a period of time. It is also possible (and entirely consistent with oral history) that whole iwi were wiped out after their arrival due to huge North Island volcanic eruptions or as a result of warfare, massacres and disease epidemics. If this is so, then whole genetic sub-groups may have been eliminated.

In science we accumulate data from different sources and from as many different kinds of information as possible to improve our knowledge. Though we have some information about the dynamics of the founding of Aotearoa New Zealand, from a number of disciplines of study, further information from different approaches will continue to enhance our ideas. The investigations described above have illustrated the fact that one facet of the history of the human race is written in our living DNA. There is undoubtedly much more to be learned about the people and places that make up our Maori culture – a culture that fits into the patterns of mtDNA variations and their spread across the Pacific that is consistent with the well-established hypothesis of the "Out of Africa" origins of all humankind.

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Acknowledgments

Author: Sue Heath, Dunedin *Editors*: Colin Walker, Rob Lynch

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Layout and design: Ruth Munro, Royal Society of New Zealand

Reviewed by: Dr Chris Cunningham, Director, Health Research, Massey University; Kay Harrison, Wellington; Pauline Waiti, Te Aute College; Kathryn Hicks, Heretaunga College.

Special thanks for support, guidance and comments from the following Massey University staff: Professor Mason Durie, Professor of Maori Studies; Professor David Penny, Theoretical Biology, Institute of Molecular BioSciences; Associate Professor Rosalind Murray-McIntosh, Honorary Officer, Institute of Molecular BioSciences (formerly at Wellington School of Medicine).

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ISSN 0111–1957
2000

The Royal Society of New Zealand