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An off beat whale hunt

Frits L Meijler

The grey whale, *Eschrichtius robustus* (fig 1), is a fascinating animal that lives for 30-40 years. The numbers of grey whales have increased since the ban on killing them and there are now about 20 000 in existence. They stay in the Bering Sea in May and June and then migrate to the lagoons on the Pacific coast of Baja California, Mexico.[1] They sleep with their heads and tails down, holding their blow holes above water (fig 2). Mating occurs in the shallow waters and strong tidal currents of the lagoons. The cooperativeness of grey whales is most obvious in the way that they overcome the difficulty of achieving coitus face to face in water. The female is supported and kept steady by another male—an unusual extension of a best man's duties.

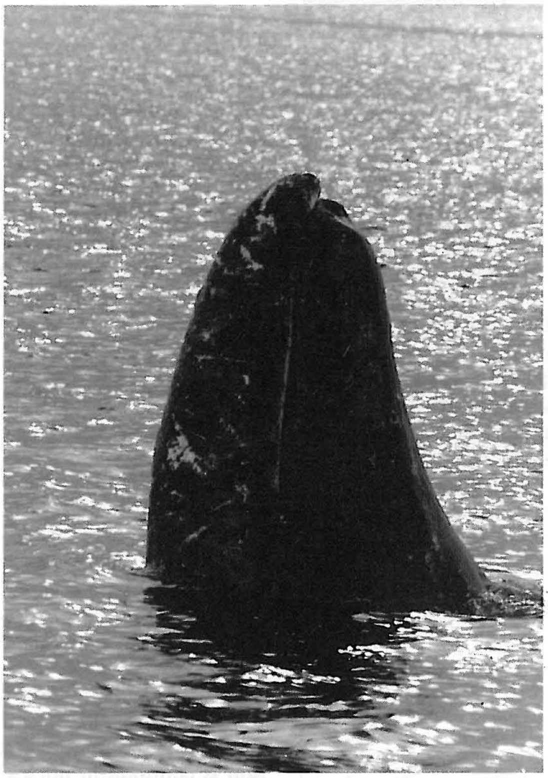

FIG 1—*Spy hopping grey whale*

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FIG 2—*Blow hole of grey whale*

Migration

- Grey whales travel 10 000 km twice a year
- Each trip takes six to eight weeks
- During the journey they swim for 20 hours a day and cover a distance of about 150 km

Grey whales are not afraid of people and actively seek out ships in the lagoons, thus allowing observers a close view and even the occasional touch (fig 3).

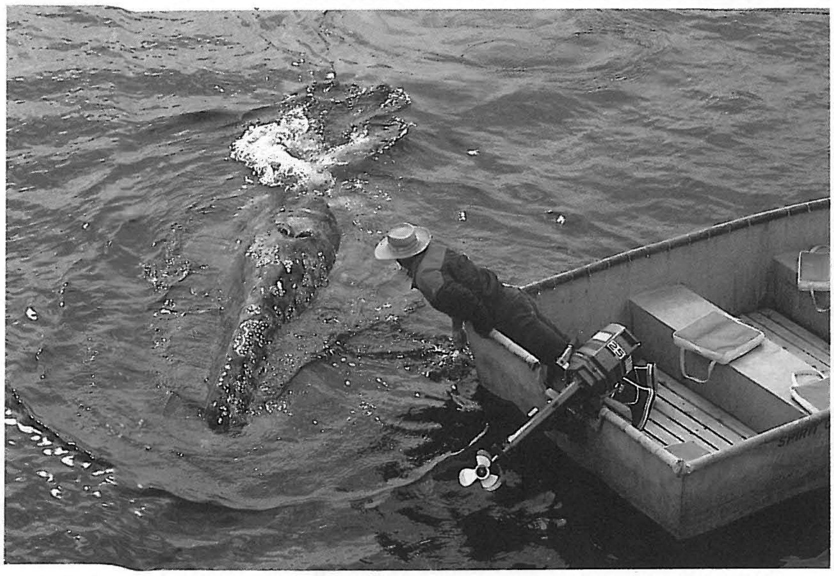
In February 1989 an expedition to Baja California was organised to record the electrocardiogram of the grey whale. The group included Dutch, American, and Mexican scientists; His Royal Highness Prince Bernhard of The Netherlands, who is chairman of the Whale ECG Foundation; Mr N F Halbertsma, director of the World Wide Fund for Nature in The Netherlands; Mr T M T M Kasteel, the Dutch ambassador in Mexico; and two professional photographers from San Diego. Prince Bernhard and Mr Halbertsma, both superb photographers, planned to make a cinefilm of the expedition and the area we visited.

We chartered a boat, the *Spirit of Adventure*, from San Diego and, with a captain and crew of seven, we set sail on the night of 8 February. After a trip lasting 20 hours in rough seas and strong winds we reached Scammon's Bay (Laguna Ojo de Liebre), about 800 km south of San Diego (fig 4). There were plenty of whales but no friendly ones and so we continued 200 km further south to Laguna San Ignacio, where we hoped that the whales would be more friendly.

In 1956 White *et al* tried to record the electrocardiogram of a grey whale in Scammon's lagoon.[2] They used harpoon electrodes that were the size of arrows and shot them into the whale from a flimsy wooden skiff. Not only did his attempt fail but it was hazardous. We decided to make use of the friendly behaviour of the grey whale. This was crucial to the success of our expedition because we wanted to apply to the whale a large suction electrode that had a small telemetric device attached to it or, if this failed, a small needle with a lead wire, and both needed to be attached by hand. Neither was harmful to the whale.

Why did we want to record the electrocardiogram of a large whale?

We believed that the electrocardiogram of a large whale would help to elucidate the function of the atrioventricular node in atrial fibrillation. Hering[3] and Mackenzie[4] found that the ventricles beat irregularly in atrial fibrillation and at a rate considerably lower than that of the fibrillating atria. By studying ventricular rate and rhythm in atrial fibrillation in several mammals,[5] we found that the difference in ventricular



VINCE STREANO, SAN DIEGO, CALIFORNIA

FIG 3—*Trying to touch a whale*

rate was small in relation to the difference in body size (table).

Ventricular heart rate in relation to body weight

	Dog	Human	Horse
Body weight (kg)	25	70	750
Ventricular rate (beats/min)	200	100	60

There is a close and linear relation between mammalian body weight and heart weight,[6] heart weight being about 0·6% of body weight.[7] Given that the conduction velocity in all mammals is probably about the same from morphological characteristics[8 9] and assuming that the atrioventricular conduction time (PR interval on the surface electrocardiogram) is a function of conduction distance, the conduction time should increase with the size of the heart and thus with the length of the atrioventricular conduction system.

FIG 4—*Lagoon and Baja California. Reproduced with permission of Roy Nickerson from his book "The Friendly Whales." (San Francisco: Chronicle Books, 1987:7)*

Figure 5 shows the relation between the PR interval and the cube root of the weight of the heart in different animal species and shows that in extremely small mammals and extremely large mammals the PR interval barely increases with the increasing length of the atrioventricular conduction system.

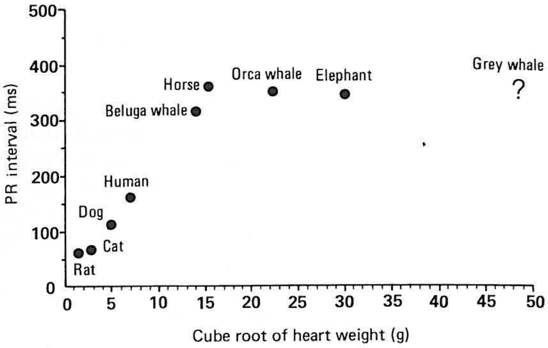


FIG 5—*Relation between PR interval and cube root of weight of heart in different mammals*

Atrioventricular conduction has mainly been studied in mammals on the linear portion of the relation between the PR interval and the length of the conduction system. The results have led to the conclusion that the impulse that leaves the atrioventricular node is the same as that which enters it—that is, that the atrioventricular node conducts. The non-linearity of the relation in extremely small and extremely large hearts, however, indicates that mechanisms other than straightforward "nerve" conduction might operate in sinus rhythm and atrial fibrillation.[10 11] By extrapolating data from the PR interval in horses, smaller whales, and elephants, we deduced that the PR interval in large whales would not exceed 500-600 ms. We therefore embarked on our expedition to confirm or refute our deductions.

In addition, we wanted to find out more about the hearts of large marine mammals because our knowledge to date came from inferences based on comparative studies in smaller animals. Large hearts, however, have a greater tendency to fibrillate.[12] The Purkinje system in the ventricles of large hearts promotes electrical homogeneity and thus helps to prevent ventricular fibrillation, but there is no Purkinje system in the atria. Is this why atrial fibrillation is common in horses?[13] And what about whales? Could cardiac arrhythmias be a cause for the beaching of whales? To protect these mammals we need to study them more thoroughly.

Results

We stayed at Laguna San Ignacio from 11-15 February, a time when grey whales usually come close to the boats.[1] We were, however, unlucky with the weather. The cold front which in September 1988 had trapped three grey whales in the ice off the coast of Alaska had reached Baja California by the time we were there and so there was more wind than usual and water and air temperatures were below normal. According to our marine biologist, Dr Theodore J Walker, this was why the whales were less cooperative than usual. We could therefore not apply the suction devices and were able only to apply a needle electrode once for just five minutes. Figure 6 shows a QRS complex obtained by signal averaging of several QRS complexes. We estimated that the whale weighed 20 000 kg, which suggests a heart weight of between 100 and 120 kg. The QRS voltage recorded was only 0·1 mV because the electrocardiogram was recorded in salt water with a unipolar lead and because the electrode was some distance away from the heart, with a thick layer of blubber separating the two. The QRS complex lasted about 200 ms, which is a short time for a heart of this size, and therefore the ventricular myocardium of the whale must contain a dense Purkinje network. The record did not allow us to draw conclusions about the characteristics of the P wave so we could not answer the question, "What is the PR interval in a heart that is considerably larger than that of an elephant?" The duration of the QRS complex does indicate, however, that the atrioventricular conduction time must be short. We found a heart rate of about 20 beats/min, which may well decrease during diving.

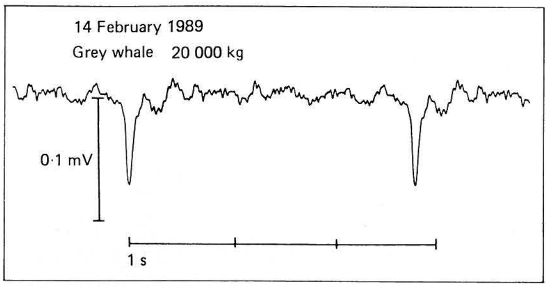


FIG 6—*Electrocardiogram recorded from grey whale showing two ORS complexes. P wave is not recognisable in noisy baseline; heart rate is about 20 beats/min*

Final remarks

Our expedition was only partly successful. We did obtain an electrocardiogram, but our short stay in the Lagoon and the unfavourable weather prevented us from using the suction electrodes and the telemetric devices attached to them. We did not record enough cardiac cycles to show a P wave, and therefore we still do not know the atrioventricular transmission time in the largest heart. The lessons we learnt will be useful in achieving success next time and the difficulties we encountered have made us realise that collecting reliable biological data in large animals is a tedious task.[14]

The expedition was sponsored by the Interuniversity Cardiology Institute of The Netherlands, the Royal Netherlands Academy of Arts and Sciences, the Minister of Science and Education, the Wijnand M Pon Foundation, the Foundation Fondsenwervingsacties Volksgezondheid (fundraising for public health), the Netherlands Heart Foundation, the Foundation Van den Berch van Heemstede, the Medtronic Bakken Research Centre, the Royal Dutch Airlines, and the World Wide Fund for Nature. A videotape recording of the expedition is available in English on VHS-PAL or NTSC at a cost of £10 inclusive of postage. It can be obtained from the World Wide Fund for Nature, Box 7, 3700 AA Zeist, The Netherlands.

Appendix

LIST OF PARTICIPANTS

The Netherlands

His Royal Highness Prince Bernhard; Mr E Vernède, secretary to HRH Prince Bernhard; Mr J J Bos, security officer to HRH Prince Bernhard; Mr N F Halbertsma, representative of the World Wide Fund for Nature; Maarten A J M Hermens, MSC, Medtronic engineer; Mr T M T M Kasteel, Dutch Ambassador to Mexico; Ron A Kastelein, MSC, marine biologist, Harderwijk; Dr Frits L Meijler, professor of cardiology, Utrecht; Dr Claes Wassenaar, physician and junior research fellow; Dr Hein J J Wellens, professor of cardiology, Maastricht; Koen J Weijand, MSC, Medtronic technician; Fred H M Wittkampf, MSC, senior research fellow and physicist.

United States

Mr Earl E Bakken, president of Medtronic, Minneapolis, Minnesota; Dr José Jalife, physiologist, Syracuse, New York; Dr Suzanne B Knoebel, Krannert professor of medicine, Indianapolis, Indiana; Dr Robert F Rushmer, emeritus professor of bioengineering, Seattle, Washington; Mr Vince and Mrs Carol Streano, photographers, Laguna Beach, California; Dr Theodore J Walker, marine biologist, San Diego, California; Dr Sylvan L Weinberg, cardiologist, Dayton, Ohio.

Mexico

Dr Anelio Aguayo Lobo, marine biologist, Polanco DF; Dr Juan Verdejo París, cardiologist, Coyoacán DF; Dr Alfredo Ortega Rubio, biologist, La Paz, Baja California Sur.

Vital statistics

- At birth grey whales are 4·5 m long and weigh 1500 kg
- They drink about 200 litres of milk a day and gain weight at the rate of 30-35 kg a day
- Adult whales are 10-16 m long and weigh between 20 000 and 40 000 kg—all this on a diet of krill

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