The internal carotid artery is reduced in function and the main blood supply to the brain is carried by a pair of large spinal meningeal arteries within the spinal canal.
These large arteries are supplied by branches from a mass of small vessels which follow a serpentive course between the heads of the ribs and the thoracic vertebrae. The main source of supply for these small vessels is the posterior thoracic artery. In the abdominal cavity above the peritoneum there is a continuous plexus of large veins into which the veins of the abdominal walls and locomotor muscles drain before entering the inferior vena cava.

The Nervous System

The delphinids have a very large, convoluted brain and are comparable with Man in the degree of cephalization. In conformity with the telescoping and rotation of the bones of the skull, the cerebral hemispheres completely overlie the cerebellum.
There is no olfactory bulb or nerve, but both the trigeminal and acoustic nerves are very large being consistent with the enbranched auditory and tactile senses. The roots and cortical centres of these nerves are also unusually large.
The brachial plexus is well developed but the iliac plexus is rudimentary and consistent with the absence of hind limbs.
The spinal nerves are interconnected in the post-thoracic region for the coordination of the locomotor muscles.

OBSERVATION ON THE BASIC NUTRITION, VITAMINS AND FOOD PREPARATION IN DOLPHINS

by C. F. G. W. van de Hurk, D.V.M., veterinary consultant to the Dolfinarium, Harderwijk, Bree 37, Rotterdam, Netherlands.

The diet of dolphins in natural circumstances is living fish. We try to imitate their habitat by providing them with clean artificial seawater, but feeding dolphins live healthy fish is at this moment too expensive. If at some future time, fish hatcheries should develop at the same rate as chicken hatcheries did in the past it could become feasible to treat dolphins in captivity to living fish. Today dead raw fish is their exclusive diet.

From the angle of medical care and science, however, dead raw fish is perhaps the most dangerous kind of food that exists. The primary cause of death in fish is asphyxia and immediately after death the structure and composition of tissue changes.

So freshness is an essential condition of the fish we want, but it is a product more difficult to preserve than any other, because the micro organisms of fish are accustomed to a temperature close to freezing point.

Freezing permits the preservation of fish for a limited time. For how long depends on when and how the fish is frozen.

Slow freezing has many serious effects on quality, mainly since it results in producing internal organic modifications. Quick freezing has the advantage of reducing the losses of cellular juice when defreezing. This exudation is very important when the fish has been frozen too slowly, since the formation of big crystals which tear up the cells leaves the fish very dry and stringy, and results in loss of savour. Furthermore, quick freezing reduces to a minimum the oxidation of fats and the breakdown of proteins. The speed of freezing should be such as to reduce the temperature in the middle of the centre of the package of fish to 5 degrees Celcius below zero as soon as possible (anyway within less than one hour). Freezing can then be continued until the temperature at the heart of the package of fish attains at least minus 22 degrees Celsius. However, I want to stress here that freezing of fish does not bestow upon the fish, qualities of freshness it did not possess before; even ultra quick-freezing, achieved under the best possible technical conditions, is unable to improve this quality in the least. Neither is deep-freezing an antiseptic; it has no sterilizing effect — whatsoever. It merely stabilizes the fish in the same state in which it is caught; paralysing the activity of bacteria in so far as the necessary temperatures are actually maintained during treatment and storage.

Consequently, deep-freezing of the fish we wish to feed to dolphins implies the strict observance of the three criteria which should characterize our operations:

1. to see that we get the best possible quality of fish;
2. to deep-freeze as soon as the fish is caught;
3. to maintain the fish under the protection of cold until prepared for feeding without any interruption or variation in temperature.

As far as the quality aspect is concerned we purchase the fish from trawlers fishing in the Western Approaches, off the west coast of Ireland and the Hebrides, and off the north coast of Scotland.

We feed both mackerel and herring, as well as some sardines and occasionally other species like caranx (horse mackerel).

We don't feed fish caught during the months of June, July and August. In this period the risk of too high an infection rate of the fish with the *Erysipelas*

bacillus may become too great; this increase results from the higher temperature of the seawater. This bacillus can also infect dolphins. At this moment I prefer to confine myself to the remark that all dolphins in Harderwijk are not vaccinated with *Erysipelas* vaccine.

Now that we feel confident that we have the right kind of fresh fish, our second goal implies that the best way would be to achieve deep-freezing on board the fishing boats. For the fishing industry this was not an easy thing to accomplish, it meant high investments, man-power with knowledge of new techniques and especially overcoming the contradiction between the regular functioning of the deep-freeze apparatus and the unpredictable odds of fishing. All these handicaps have been dealt with meanwhile and in Harderwijk we only accept fish from very modern fish trawlers, equipped with deep-freezers with a capacity of minus 40 degrees Celsius on board, which can store frozen fish at minus 22 degrees Celsius during the voyage.

In order to prevent internal organic modification and to avert dessiccation and oxidation we store the fish at about the same temperature which is obtained in the centre of the product during freezing: minus 18 degrees celsius as a minimum, in fact between —22° C and —28° C. Remember that fat fish requires a lower storage temperature as the danger of the oxidation of fats is greater.

Experience has taught us that the frozen fish should be defrosted slowly in order to keep a firm texture. Our routine is as follows: the fish to be fed on a certain day is taken out of the deep-freeze in the afternoon of the previous day; part of it is defrosted for immediate use, the rest (to be fed later during the day) is kept in a refrigerator at a temperature round about zero until needed.

Early in the morning the fish used for training and show is cut. It should be noted that the intestines, together with other organs which can accelerate the deterioration process of the fish, are removed from 60% of the fish; about 40% of the daily ration is given as whole fish, so as to make sure that the dolphins get their rations of fish liver, which provides a vitamin supply. A daily fish ration is 3-5 Kg.

The fish is never thawed in water, because this procedure would extract and dilute the important body fluid and the fish will consequently loose their firmness. Before being stored in the cooler the defrosted fish is washed as it is believed that in this way it will absorb some of the water that is lost during the deep-freeze process and storage period.

The hygienic aspect

As mentioned before fish is most susceptible to microbial changes and it is evident that the preparation of the fish to be fed cannot be effected under absolutely aseptic conditions. It can therefore be surmised that the fish is con-

taminated superficially during defrosting, cutting etc. The quantity of microbial germs depends therefore on the observation of sanitary regulations.
Needless to say that all equipment used should preferably be made of stainless steel and should be kept scrupulously clean by washing after every use. Trainers, and especially staff who prepare food, should be impressed with the importance of keeping clean all utensils like knives, buckets etc.; to cut their nails regularly and to wash and desinfect their hands before starting work. We also order them to use clean towels after every visit to the toilet; they should understand that these hygienic precautions are of paramount importance in order to safeguard the dolphins health.

Parasites

Deep-freezing fish is the most effective method of killing host parasites; it is therefore the obvious measure to prevent parasitic diseases, not only in dolphins but also in human beings when the latter are used to eating raw fish.
The majority of people in Holland consume raw salted herrings, especially during the summer months. In Holland only a few years ago a law was enforced to keep salted herrings deep-frozen for several days immediately after catching, if they are to be sold for human consumption. In this way the parasitic infection in man caused by *Anisakis* has now been brought fully under control.

As soon as frozen fish is defrosted it becomes very sensitive to oxygenation, autolysis, bacterial contamination and deterioration and we will give you now some examples of dangerous and even poisonous compounds which one can come across in dead fish materials.

Vitamin B_1.

Dolphins, newly arrived from Florida U.S.A. in Harderwijk, start eating dead fish without vitamin B complements after fasting during transport. It was remarkable to diagnose that most of the dolphins expelled dead tapeworms during the first week in their new home.
The same phenomenon can be observed in cats infested with tapeworm. Whenever these cats eat only raw fish they usually expel their tapeworm. The most acceptable explanation for this phenomenon is the activity of thiaminase in dead fish. Thiaminase is an enzyme, which is hydrolizing thiamine; the latter is the chemical formula of vitamin B_1 or aneurin HCL. By destroying vitamin B_1, thiaminase acts like a poison and can cause severe symptoms of illness in several kinds of animals.

The enzyme is also found in some plants. Very well known plants containing thiaminase in their leaves are bracken *(Pteridium latmusculum* and *Pt. aquilura)* and also very well known is the mare's tail *(Equisetum arvense).*
Poisoning symptoms in horses and ruminants grazing on pasture on which considerable quantities of mare's tail is found or eating hay containing relatively large amounts of these plants, sometimes develop severe symptoms of poisoning resulting in lameness; and these symptoms can be successfully treated with thiamin. In the intestines of carp and goldfish *(Carassius carassius)* the thiaminase can be formed by certain hitherto undetermined bacteria which produce this enzyme in large amounts.
Also in crustaceans *(Penaeus caramote)* and in some molluscs *(Tellina)* important quantities of the enzyme is sometimes found.
The so called 'Chastek disease', an acute lameness from which mink and foxes may suffer and which may spread unexpectedly on fur farms where only fish is fed, is a typical case of thiaminase poisoning.
In 1969 A. Helgebostad in Norway made some experiments on mink, feeding them silver cod *(Gadiculus thori).* Feeding this species of fish caused inappetence on a number of mink farms. By the thiochrome method, high thiaminase activity was evidently shown. One gram of either the stomach and its content, or of clean fillets, destroyed 92 micro gram vitm B_1 and one gram of the gills and fins destroyed 96 micro gram vitm B_1 in two hours at 37 degrees Celsius.
Since 1965 all dolphins in Harderwijk have daily received one tablet of 50 mg. vitm B_1 (thiamine). This preventive dosage is of an estimated size, based on the fact that the dolphins are eating an average of 5 Kg. of fish a day.
My colleague J. White, veterinary consultant to the Seaquarium Miami, advises a dosage of 250 mg. vitm B_1 daily. In warmer climates and when no instantly deep-frozen fish is available high dosages like these are perhaps necessary. I would like to mention, that in laboratory animals and even human beings high dosages of vitm B_1 have proved to be toxic. Blockage of the breath centre in the central nervous system and death by complete paralysis can occur. We have never encountered any problem with a 50 mg. dosage, but of course that was under the conditions we have established here in Harderwijk.
In our opinion it is of the utmost importance to improve the quality of the fish i.e. by making use of deep-freeze trawlers and in our humble opinion deep-freezing is better than searching for chemical preservatives with which to treat inferior fish.

Vitamin E

The fats of herring and mackerel have a high content of unsaturated fatty acids. Oxidation during defrosting and handling the fish before and while feeding them is virtually unavoidable. Oxidation attacks the fish very soon after de-

frosting and the oxidation of the fatty acids gives the fish a taste and smell of cod liver oil. For all mammals and birds rancid fat creates nutritional problems. Apparently it acts as a poison, depending on the quantities taken. Dogs, for example, can stand a high percentage of animal fats in their ration. To what extent commercial fat qualifies for use in the manufacture of dry dog foods, depends on the rancidity rate. The free fatty acid contents of the ether extracts can be used as an estimate of their rancidity. If the rancidity rate is to high a toxic diarrhoea develops in dogs.

Both vegetable oils and fish oils may contain toxins and some of them are thermostable (they do not disappear by heating). Toxins were found when analyzing commercially available refined fats, which were aerated at 160° C for four days.

First example: Feeding week-old chicks a purified diet containing 20% of a heated cotton seed oil resulted in 100% death of the birds in less than two weeks. A remarkable finding was that the addition of 100 I.U. vitm E per Lb. of cotton seed oil prevented this fatal outcome. Apparently the saponifiable part of the oil caused the disease.

In 1965 a high mortality in chicken fed with menhaden oil, an oil obtained from fish, was observed. The chickens showed symptoms as early as on the 9th day that they were taking the ethyl esters or reconstituted triglycerides obtained from the poly-unsaturated fatty acids of the fish oil.

Second example: In the years around 1953 a widespread liver disease in Sweden among pigs, the so called hepatotoxicosis, was observed among pigs from 3 to 15 weeks old. The pigs died suddenly or after a short period of inappetence and dullness. The diet fed ,contained 6% cod liver oil. The liver injury can be prevented by adding alfa tocopherol (vitm E) to the diet.

In 1968 the same hepatotoxicosis was observed in mink farms and could be associated with feeding toxic herring meal. The same disease was earlier observed in Norway in 1960. The liver disease ravaged some 70 mink and fox farms in the years 1960 to 1966.

The progress of the disease is slow in most cases. The animals are limp, and lose their appetite prior to death. Feeding experiments on mink and blue foxes with herring meal which had proved toxic for sheep, resulted in the production of similar liver disease.

During the production of herring meal both trimethylamine and lower amines can be present in the fish sludge, when the period between actual catch and date of meal manufacturing is excessively long. Bij adding large quantities of nitrites, the toxic substance dimethylnitrosamine is created, a product of the reaction between nitrites and the amines. It should be noted that when large quantities of nitrites were added as a preservative to fresh herring, however, no toxicity was observed in mink.

Third example: Cod liver oil can be toxic for mammals. In 1955 it was observed in England that the daily addition of 1—4 oz. cod liver oil to the daily ration of dried skimmed milk resulted in death or in severe muscle dystrophy in a high proportion of 28 Ayrshire bull calves. It was concluded that the toxicity of cod liver oil to calves was due to its content of polyunsaturated fatty acids. Daily oral administration of 200 mg. alfa tocopherol (vitm E) prevented muscular dystrophy. Administration of the same dosage by intramuscular injection did not protect the calves.

Several authors and institutes report that by adding cod liver oil to the rations of different kinds of mammals, symptoms can occur of vitm E deficiency. The so called 'Yellow fat' disease is associated with feeding certain types of fish or with the addition of cod liver oil to rations. The disease is not only recognized in cats but also evident in mink farms and in other species of animal. The administration of vitm E (tocopherylacetate) for several weeks may reverse the degenerative changes. The drug may also be successfully used prophylactically. It was observed that 25 parts per million alfa tocopherol in the rations of mink prevented all the deficiency lesions.

Fish liver oil added to the diet greatly accentuated vitm E deficiency in breeding turkeys; fertility was reduced.

Alfa tocopherylacetate counteracted the deleterious effect of fish oil on hatchability, but the tocopherol content of the yolk of the eggs was not appreciably increased by vitm E even though hatchability was near maximum.

It is difficult to explain how in general the deficiency symptoms arise. Cod liver oil contains from 10 to 30 milligrams vitm E for each 100 gram. Some authors suggest that the deficiency symptoms are due to the action of the unsaturated fatty acids rather than to deficiency of the vitamin. In rats fed 30% cod liver oil in the diet (the oil containing 10 mgr. vitm E per 100 gram) deficiency symptoms develop. The composition and quality of cod liver oils seems to vary considerably and it would be reasonable to accept that temperature and freshness of the fish and hygiene during manufacturing the fish oils differ considerably.

From all these facts one conclusion can be made: alfa tocopherylacetate (vitm E) has a protective value against toxins that may develop in fish. Since 1965 every dolphin in Harderwijk has been administered a daily dosage of 5 ml. natural wheat germ oil. Wheat germ oil is a biochemical complex containing substances many of which are still unidentified. In the past, difference of opinion has existed on account of the assumed equivalence of wheat germ oil and vitm E and this has resulted, in several instances, in misinterpretation of research data. With recent discoveries of the beneficial effects of wheat germ oil on reproductive processes in man, cattle, sheep and laboratory animals, as well as the physiological effects on oxygen uptake and endurance of both wheat

germ oil and octacosanol, it appears that a re-evaluation of these natural products would be in order.
It is in our opinion imperative to mix vitamin E (the wheat germ oil or the alfa tocopherylacetaat) in the daily ration of dolphins, as this is a 100% fish diet. Injections of vitm E are ineffective, or at least, less effective. The vitm E proved soluble in fats and acting as an antioxidant it protects the vitm A already present in fish food.
In cellulair metabolism it is thought to prevent peroxidation of unsaturated fatty acids.

Vitamin C

Other antioxidants like vitamin C (ascorbic acid) and citric acid have also to be considered of value in the 100% fish diets we are discussing here. Both are easily soluble in water. They can be used temporarily or daily in small amounts to protect the fish food from undesired oxygenation processes during digestion. Like vitamin E they can play a role in the metabolism of lipoïds.

Vitamin K

To the daily dosage of vitamin B_1 and wheat germ oil we add one tablet of vitamin K, containing 10 mg. menadioni natri bisulfis (vitamin K_3).
In the intestines of man and other mammals vitamin K is formed by the coliform bacteria that live there. The vitamin can also be found in fresh vegetables. If the intestinal flora is partly or completely destroyed the natural production of the vitamin by the coliform bacteria stops immediately, which may cause severe symptoms of poisoning. In common veterinary practice a situation like this can unexpectedly arise after administration of antibiotics and it is clear that only vitamin K counteracts the poisoning symptoms.
It is a well known fact that the anti-bacterial activity of fish oils is very high. By oxygenation peroxydes and aldehydes develop, and for this reason cod liver oil can be used in ointments for the treatment of wounds with striking sterilizing effects. Since we know next to nothing yet about the normal intestinal flora of dolphins we are not sure this flora can always produce vitamin K in sufficient amounts.
Though the vitamin was found in rotting fish meal in the United States by Dorsey in 1939 we have no empiric evidence about the vitamin K content in fresh raw fish. We can therefore hardly assume that fresh fish food is to be seen as a sufficient natural source of this important vitamin. Like vitamin E this vitamin K demonstrates an impressive activity: it stimulates the metabolism of liver cells and of capillary endothelian cells.

Testing the antibacterial action of vitamin K it was found that staphylococcus aureus and staphylococcus albus were to be particularly sensitive. The vitamin also has fungostatic activities on several dermathophytes.
Considering these facts we were of the opinion in 1965 that it could be important to add a daily dosage of this vitamin to the diet of the dolphins.
With regard to other vitamins it is a well established fact that fish liver contain the vitamins A and D and the vitamins of the B group in sufficient amounts. Nevertheless all our dolphins are administered a coated multivitamin tablet thrice a week as a supplementary measure. This tablet contains in addition to minerals the usual range of all vitamins in quantities commonly required for the benefit of pregnant women (Gravitamon, Organon).

Epilogue

I have only given you a brief introductionary description of the basic nutrition problems we meet with in our dolphins, of the experiences gained, and some of my reflections on supplements to the diet of dolphins in captivity. If my observations have not been very illuminating and seem more like candles than searchlights, let it be remembered that we are dealing with a complex problem which can only be tackled by exchanging accumulated experience. Progress in developing the ideal conditions for our dolphins will not be quick and dramatic; it is rather a matter of careful multi-disciplinary study and survey.

SUPPLEMENTARY NOTES ON DEEP FREEZING

The start

The idea of applying low temperature for the preservation of food was first put into practice by a Frenchman, Charles Teller, in 1868. At about the same time the deep-freezing of fish started with experiments in the U.S.A. but real strides have been made since 1923 when Clarence Birdseye set up a company in New York for the purpose of quick-freezing fish.

In Great Britain the first plant for fish deep-freezing was founded in 1930. As deep-frozen fish in those days was only sold in periods of real want, the quality was sometimes affected by storing for too long.

Deep-frozen fish was introduced into Germany under the most deplorable conditions, during the last war. A terrific amount of deep-frozen fish, mostly of mediocre quality before the freezing process, was thrown on a market insufficiently equipped for storing.

In France a private company fitted out two trawlers in 1930-31 for deep-freezing, but these ships were destroyed during the war.

What deep-freezing is.

All freezing processes, whether slow or quick solidify, during preservation, foods which usually have a water content of 75-90%. In this way, freezing imprisons the micro-organisms in the ice thus formed and arrests to a large extent the biochemical phenomena of decomposition. During the freezing process, the water leaves the cells and freezes outside in the form of ice crystals. The crystals - and this is where we find the criterion of distinctions between slow freezing and quick or deep freezing - become bigger and sharper in inverse proportion to the speed of the freezing process.
Slow freezing causes the tissues to be torn, with a resulting loss in food value; when thawed, the fish has a flaccid and soggy consistency. The deep-freezing process requires a freezing speed sufficient to bring down the temperature from zero to minus 5 degrees Celsius within the shortest possible time (not exceeding 30 minutes) as it is between these two temperatures that the formation of ice crystals takes place. To freeze most of the water content in fish it is necessary to bring down their temperature to below minus 18 degrees Celsius.

Wrapping and storage

Wrapping plays an important part in the preservation of deep-frozen fish. Its main purpose is not for packs of frozen fish to be handled easily, but to oppose desiccation caused in the long run by the loss of humidity.

Once the fish is deep-frozen and its temperature brought down to minus 18 degrees in the centre of the packs wrapped in plastic sheeting, it should be kept strictly at the same temperature until used for feeding the dolphins. This is very important as liquid water remaining inside the deep-frozen fish allows micro-organisms to grow. Even partial thawing is fatal as that moment all the disintegrating processes will resume their activity and will affect the fish rapidly and irremediably.

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