DIRECT EXAMINATION (Continued)

Q. Doctor, in the course of your consideration of the transport system involved in the dislrihn1ion of biologically active materials, have you had occasion in the course of your regular professional studies to rely upon the work of people at the Oak Ridge National Laboratory"!

Yes, I have.

Q. Are these individuals full-time employees of the Atomic Energy Commission”?

A.Yes, they are.

Q. Can you name them?

A. Dr. Jerry F. Olson [and] Dr. Robert O’Neil, both of Oak Ridge National Laboratory; Dr. Jerry S. Kline of Argonne National Laboratory, whose specialty is tritium; and Dr. Stanley I. Auerbach at Oak Ridge National Laboratory.

Q. Doctor, in the course of your regular professional activities, have you ever had occasion to appear in a judicial proceeding before”?

A. Yes, I have.

Q. And did you appear in one for me as a witness when I called you back in May of this year?

A.Yes.

MR. EARDLEY: Your Honor, I object to this line of testimony. What difference does it make whether he has appeared with Mr. Yannacone before”?

MR. YANNACONE: Subject to connection, we have a number of documents that we have to get in and we’re going to meet the same set of objections.

THE COURT:Go ahead.

Q. Doctor, did you appear at this hearing today pursuant to subpoena?

A.Yes.

Q.Did you receive that subpoena in this courtroom”?

A.Yes.

Q. Did you receive a telephone call from me telling you that you were going to get a subpoena?

A. Yes, I did.

Q. Did you receive a telephone call from me telling you that I had requested the Atomic Energy Commission to produce you? as

A. Yes.

Q. Doctor, in the course of the preparation for the prior proceedings we participated in together, we collaborated for a number of months, did we not?

A. Yes.

Q. During the preparation for this proceeding, in view of the fact that you were formerly a consultant for the Atomic Energy Commission, we have not collaborated in the preparation of the testimony, have we?

MR. EARDLEY: Now just. a moment, Your 1-lonor. This 1s going too far.

THE COURT: The objection is sustained.

Q. Dr. Loucks, with respect to the consideration of a system of transport mechanisms in air, water, land biological systems involving the distribution of biological active material, are the elements of the systems analysis itself independent of the nature of the material?

A. The primary transport processes you mention by which there is exchange in the system are the same regardless of the material that may be moving through the system.

Q. In other words, then, Doctor, to properly describe a system we describe two elements, the first of which arc-

MR. EARDLEY: I am going to object. He's leading the witness right down the path.

MR. YANNACONE: He is a consultant for the Atomic Energy Commission, Your Honor, on matters that I haven't had a proper opportunity to prepare. He is here under subpoena.

TIIE COURT: Well, you said, as I understand you, you collaborated for months.
MR. YANNACONE: On DDT, Your Honor.
THE COURT: So, the objection is sustained. Proceed.

The direct testimony then considered in more detail the characteristic of the individual regional ecological systems operative within the Colorado Regional Ecological System.

Q. Doctor, will you discuss the basic elements of the water transport system in two aspects, one involving that portion which is variant, and a function of the transport mechanism, and the second that which is dependent upon the chemical and physical properties of the material to be transported"?

A. Yes, the primary transport system is the movement of the water through the system itself. I listed seven or eight variables into which incoming water precipitation can be partitioned. The processes whereby it goes through this partitioning are such processes as evaporation, infiltration, gravitational flow, absorption by plants, and related transformations. This is essentially the system for material that is the carrier system. In addition, we have the transporting material, a material that may be in the water, for example, nitrogen, DDT, or tritium, but each of these materials will go through the processes at some rate that is somewhat different than that of the water.

Q. In other words, then, Doctor, once you have adequately described the water transport function in the water transport systems, and then the physical and chemical properties and the biological activity of the material, you can utilize your systems model and come up with some predictable statements about the distribution of the biologically active material, is that correct?

A. If the chemical and physical properties are well-enough known, one can make the adjust men l in the system to achieve a prediction of the flow of the carried material. In

many cases the properties are not well-enough known to make this prediction, however.

This characterization of the physical transport systems was followed immediately by characterization of the biological transport system.

Q. Doctor, would you describe for us the biological transport system as an element of a systems analysis as it affects the transport or a biologically active material such as tritium"?

A. The biological transport system consists of plant roots which absorb water from the surface layers of the soil; water, which enters the conducting system of the plant and in the leaves, and may be either transpired into the atmosphere or may, at that point, react with carbon dioxide and through photo-synthesis become replaced in sugar molecules in the leaf which in turn can become replaced in starch or cellulose molecules of the plant tissue. The transport system continues then through what is referred to as another trophic level, another partitioning of the movement of materials upward through the food web when grazing animals, and this may include mice as well as cattle, feed on that herbage and utilize primarily the carbon and water that has been mixed in sugars and cellulose. But to the extent that tritiated water may have been a part of the waler incorporated in sugar molecules, it can continue to be a component of cellulose entering the digestive tracts of the animals feeding in the next trophic level.

Considerable evidence was introduced on the photosynthetic process in primary producers, the role of water in the photosynthetic process, and the potential for the incorporation of tritium in the formation of plant sugars during the photosynthetic process. After establishing the characteristics of the trophic level of the primary producers,

the witness proceeded to consider higher trophic levels in the system.

Q. Doctor, in the course of your review of the government's little pamphlet on tritium, is there any evidence indicating the way in which tritium enters the plant world as such"?

A. There is really a very cursory treatment of the potential for tritiated water to be taken up in the sugar cellulose molecules ....This paper is a review of the existing literature at the time that the review was made, and the author is able to simply cite what had been done up to that time and he points out that there seems to be... an incomplete reversibility of tritiated water vis-a-vis the ordinary water molecule indicating a selective uptake in cellulose.

Q. Doctor, in the course of your regular professional education, you became involved in the subject of botany, did you not?

A. Yes.

Q. You have a degree in it, don't you?

A. Yes.

Q. You [supervise] a number of Ph.D. candidates in it, don't you?

A. Yes.

Q. Doctor, would you please for the record explain very briefly the mechanism of the fixation of energy in green plants and the place of water vapor, tritiated or otherwise, in this process?

The Court permitted Dr. Loucks to use a chart.

A. This is essentially the photosynthesis reaction where we see the uptake of carbon dioxide combined with water, for which, as we see from this review, there is just a little evidence of selective substitution of tritiated water, but so little evidence that we simply have to view this as a void, as a gap in the knowledge... that we have to view the potential for selective substitution of tritiated water at this role in the equation as substantially unknown at this time. We have an input then of

energy to bring about the synthesis of carbon dioxide (CO_2) and water (n_20)-sunlight at appropriate wave lengths. To balance the equation. we want to take $6CO_2$ + 6 ^{3}HP (tritiated water) which will give us bigger molecules, then, C6N12O6, plus the release of oxygen, 602.

Q. And that's the basic photosynthetic reaction, is it not?

A. This is the basic photosynthetic reaction which requires water as a substrate. The secondary reactions that are of some interest are the reduction of sugar, C6H66, to starch or cellulose, as the case may be. as a storage or growth material in the plant.

The same sugars, of course, are the building blocks of the more complex molecules which the review by Jacobs points out do take up tritium and retain it. particularly DNA.

Q. Doctor, what is the basic constituent of cellulose?

A. Sugar in reduced form.

Q. Doctor, when the green plants are grazed by the next trophic level above, what happens"!

A. Of course, all the contents of the green plant are immediately ingested and any water in the plant, which might include tritiated water not found in cellulose. will then move into the water circulation of the grazing animal. On the other hand. the sugars, starches, and cellulose can he broken down by the grazing animal and utilized as building materials in the tissue of that animal.

Q. In other words, then, Doctor, there are two separate processes and mechanisms involved within this grazing animal, one for the water which is not bound in the green plant and is simply carried by it, and the other which is hound in the chemical elements of the green plant?

A. That's right.

Q. Doctor, how much of this material that is ingested is retained by that grazing animal?

A. It would depend on the age of the grazing animals. What we are concerned with here is that, in general, about fifty per cent of the energy intake, that is, the energy contained in the bonds of those sugars or cellulose molecules, will be utilized in respiration, that is, essentially in the release of heat to maintain body warmth and activities of the grazing animal. Of the remaining fifty per cent, a portion will be excreted, and a portion will be utilized in the building of tissues so that we have then in the grazing animal the reduction of approximately fifty per cent of the sugars or cellulose, the $C_6H_{12}O_6$ equivalent, the reduction of this material to its components, carbon dioxide and water, and these are returned then to the atmosphere... And a portion of the remainder remains with the grazing animal; that portion which is not excreted.

Q. When the grazing animal is preyed upon, eaten, or otherwise consumed, does the same process repeat?

A. Yes, the same process repeats as we move through each predator-prey level referred to as a new trophic level, and we have the same utilization of approximately fifty per cent of the intake in simply burning off the intake and the storage of a portion, a major part, of the remaining intake.

Q. Doctor, in the course of your regular professional activities, have you had occasion to investigate the phenomenon commonly referred to as biological concentration"?

A. Yes.

Q. Have you had occasion to investigate the phenomenon with respect to biologically active materials such as DDT?

A. Yes.

Q. Doctor, in the course of your regular professional activities, have you prepared documents for publication on the basic phenomenon, the biological concentration of DDT"?

A. Yes, I have.

Q. And did you do this alone or in concert with others?

A. Well, because, again, the study of biological concentration or magnification of a transported material in a complex system extends beyond the capabilities of any one scientist, this kind of research is acknowledged in almost all laboratories I know of as being the responsibility of a combination of scientists, and in the case of the DDT study and manuscript we have now submitted for publication, the combination of people working on it included...

MR. EARDLEY: Just a moment. I would like to have Mr. Yannacone explain how DDT got into this cavity. Otherwise, I think it is immaterial.

Q. Doctor, in the course of your regular professional activities, have you had occasion to investigate the concentration or biological magnification of biologically active substances in regional transport systems"?

A. Yes, I have.

Q. Have you had occasion to deduce any general principles with respect to the process of biological magnification and concentration as a result of this study that are essentially independent of the physical and chemical 1m1pcrties of the biologically active material under consideration"!

A. Yes, we have arrived at evidence of significant time lags in the development of the magnification and in the expression of the magnification that seems likely to be independent of the material.

Q. Doctor, so that we can understand the process of modern ecological research in ecological systems today, would you please tell us the place of the consideration of the actual transport of particular radionuclides throughout a regional transport system mad the ultimate mathematical systems description of that trans1lort system?... Would you outline briefly for us the elements of ecological research in systems today — modern ecological systems research — and indicate the role the general data regarding the place radionuclides and other biologically

concentrical materials play in the systems study so that the general systems characteristics may he determined?

A. Well, we have to look at the biological transport system the same way that we look at the water transport system and recognize that the primary transport through the system is of energy, and that there are certain processes, approximately a dozen processes, involved in the exchange and transfer of energy in this system, we have to distinguish the analysis of the energy from the analysis of the transported material, such as tritiated compounds, in the biomass of these materials, which may not be transferred at the same rate as the transfer of energy itself. This is the primary conclusion that we arrive at from analysis of DDT [transport]. We find that the physical and chemical properties of the material will determine its rate of concentration, its rate of magnification, in the biological transport system.

Q. Doctor, in order to properly determine the systems characteristics of the trophic level biomasses in a complex ecosystem such as the ones that you have considered]in your systems papers, with respect to your systems analysis [of] the transport of the biologically active material DDT, did you have need to rely upon information with respect to the transport of radioactive materials and radionuclides in similar ecosystems?

A. Yes, as I have indicated, our understanding of these systems to a great extent today rests on certain research begun in the early 1950s, particularly at Oak Ridge National Laboratory, and continuing to this time. However, the taking-up of this technique of systems analysis by other groups studying biological systems across the country has led to certain innovations in the technique that are now independent of the original work that focused primarily on radionuclides.

Q. Well, the passage of radionuclides through an ecosystem, by virtue of the very physical properties of radionuclides, are easy to spot, aren't they?

A. They are easy to spot, and they are the material that has given rise to most of our present conception as to the nature of [material] movement in ecosystems.

Q. And as Dr. Schultz indicated, much of the work that has been done depends upon the studies with Ccsium-137 and n3l and fallout products such as Stroutium-90? MR. EARDLEY: Now, Your Honor, would you instruct Mr. Yannacone to let the witness testify? He hasn't been sworn and he has been doing all the testifying here.

MR. Y ANNACONE: I am not competent to testify.

THE COURT: I think he is just hurrying it along... Go ahead, the objection is overruled.

A. Yes. All those materials, all those radionuclides, have been used in the investigation of ecosystems and that isotope Dr. Schultz in particular mentioned, Cesium-137, has been particularly important.

Q. In the systems studies, is it possible to indicate qualitatively any of the criteria determining the time which it takes a given biologically active material to attain dynamic equilibrium at any given trophic level?

A. Yes, in the analysis of DDT, we had sufficient data available that we were able to show that the time lag involved in reaching equilibrium levels of DDT at the top of the trophic system, at the top of the food web...

Q. By the way, what is the top of the food web?

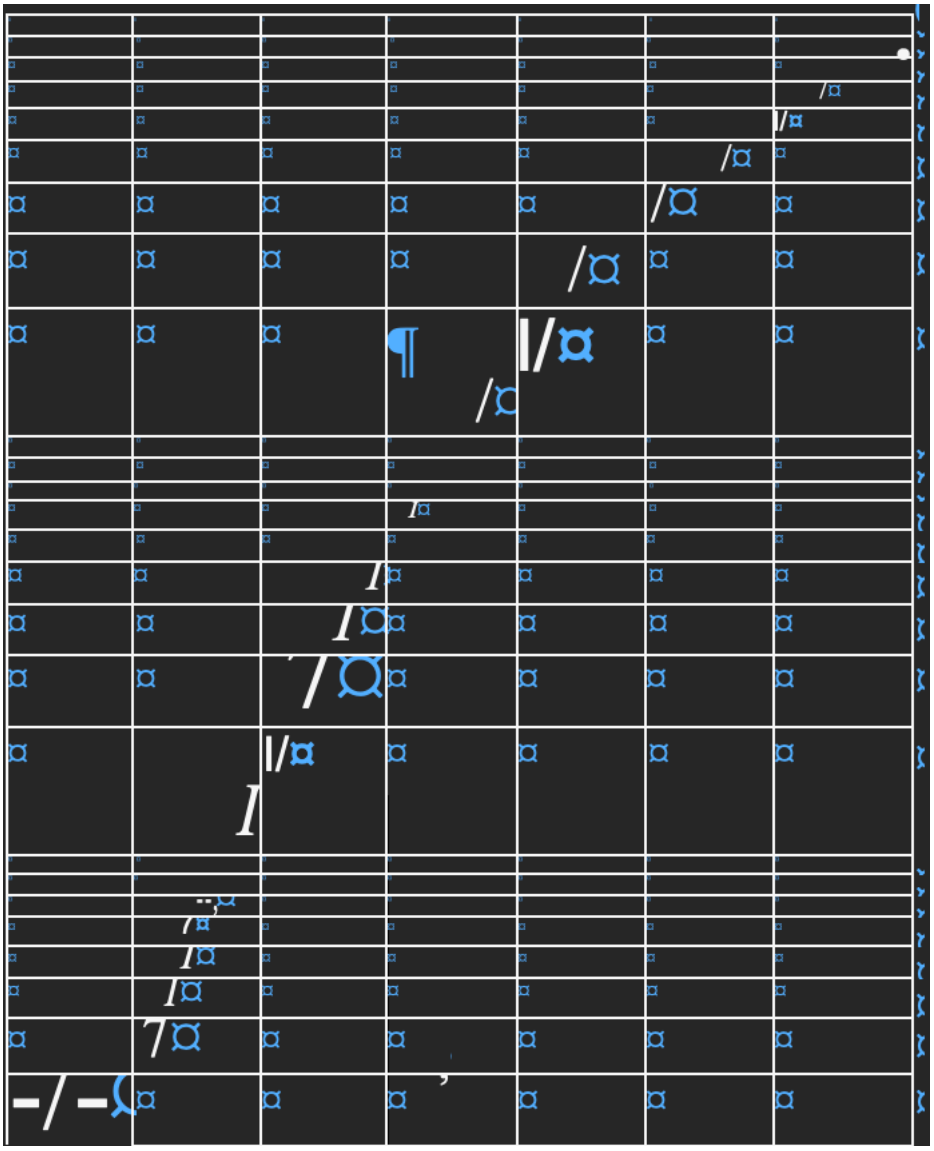
A. The top of the food web is represented by the top carnivore. That is, a species that preys primarily on other carnivores and which itself is rarely preyed upon. The Peregrine falcon is one of our best examples, also the bald eagle... To the extent that we [human beings] utilize meat in our diet, we are a top carnivore, but to the extent that we shift and become

vegetarians we are less of a top carnivore. The time lag involved in achieving equilibrium levels with a contaminant such as DDT can be shown from an analysis of a system of differential equations that describe the changes in that system as at least equal to the lives of the longest-lived species in the system. That is, you cannot get equilibrium at the top of the system until you have reached equilibrium all the way up through the system, and this is a function of the longevity, and in some of our top carnivores, such as the bald eagles, we have time lags of thirty lor forty years.

Q. I show you a graph which is entitled "Dose Rate to Body Tissue of the Worldwide Population from Tritium as a Result of the Ingestion of Drinking Water and of Inhalation and Skin Absorption of Water Vapor. …

Doctor, I want you to look at that graph and indicate whether or not that indicates from purely a mathematical point of view any points at which dynamic equilibrium of tritium in the trophic level occupied by man may he reached"!

A. This is worldwide accumulation and for the year 1970... it shows two times ten to the minus six millirems per year. By 1985 it is ten to minus four millirems per year. By the year 2000, it is ten short of ten to the minus three millirems per year, indicating a continuing buildup which clearly is not reaching an equilibrium level.



The graph showing the data, not the entire paper in which it appeared, was offered into evidence and admitted without objection.