

The Specific Labeling in Hypertonic Medium of a Spleen Protein

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The biosynthesis of a 12000 dalton protein species released into the medium by mouse spleen was resistant to the inhibitory effect of hypertonic medium on protein synthesis. This protein fraction comprised 10% or more of the total radioactive protein in the medium but could hardly be detected in the spleens. It was labeled very often to a higher extent in diseased animals. It is not related antigenically to either β -microglobulin, mouse-interferon, or to mouse immuno-globulins. A preferential uptake into cells of certain organs, which, when themselves incubated in organ cultures did not synthesize and release the protein, was observed.

Introduction

Cellular protein synthesis in tissue culture is reversibly sensitive to medium hypertonicity [1–3]. Since viral protein synthesis very often is less sensitive to hypertonic medium conditions, this technique has been used to label preferentially the proteins of DNA-[4] as well as RNA viruses [2, 5, 6]. We intended to use this technique to investigate the protein synthesis of spleens from mice inoculated with the agent of the scrapie disease. This agent causes a so-called slow virus disease of the nervous system in sheep and goats as well as in the experimental mouse system [7, 8]. Although we have not detected any scrapie agent-specific protein synthesis, we made the observation that medium hypertonicity did not block the biosynthesis of a relatively small spleenic protein secreted into the medium. These experiments are described in this communication.

Materials and Methods

Animals

Mice of the inbred strain STU [9] were used. Animals were inoculated [10] either intracerebrally or intraperitoneally at 4–6 weeks of age with normal or scrapie brain dilution of 10^{-2} – 10^{-3} . The scrapie agent was obtained from Dr. R. Kimberlin

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and colleagues at the Institute for Research on Animal Diseases, Compton, England. The material was passaged at least twice in STU-mice before use.

Organ culture

Organ cultures were performed using Medium 199 [11] with Hank's salt solution [12] from which leucine had been omitted. To the medium were added 0.030 M HEPES and antibiotics. Hypertonic medium was prepared by addition of 8 g NaCl/l to the above [3].

Two spleens (150–280 mg) per sample – removed 10–50 days after inoculation – were incubated in a 25 ml-Erlenmeyer flask containing 3 ml of medium. Radioactive leucine (Amersham-Buchler, Braunschweig, Germany) was added (25 μ Ci/ml), and the sealed flasks were kept at 37 °C on a rocking table for periods of 36–70 h. The medium was then removed for protein isolation. The spleens were again incubated twice for 1–2 h with Dulbecco's modification of Eagles minimum essential medium [13] to effectively eliminate free radioactive leucine. This medium was discarded. The spleens were stored at –20 °C until use.

Isolation of proteins from the culture medium and gel electrophoresis

The incubation medium was centrifuged at $500 \times g$ for 10 min to remove particulate material. Protein was determined in 0.1 ml of the supernatants. The supernatants were then passed through a column (30 × 1.5 cm) of P10 (Bio-Rad, München, Germany) to separate the high molecular weight protein fraction from free [3 H]leucine. Gel electrophoresis was performed according to Laemmli [14] at a concentration of 12.5% polyacrylamide of the separating gel on 25–50 μ l samples out of 10 ml of the high molecular weight fraction. After electrophoresis the gels were frozen at –10 °C, and cut into 1 mm slices. These were incubated in 0.2 ml Soluene 300 (Packard Instruments, Frankfurt/Main, Germany) at 50 °C for 2 h and were then counted in 2 ml of a toluene based scintillator solution.

Protein determination

Protein concentrations were determined with Coomassie Brilliant Blue G-250 (Sigma, Heidelberg, Germany) according to Bradford [15] using bovine serum albumin as a standard.



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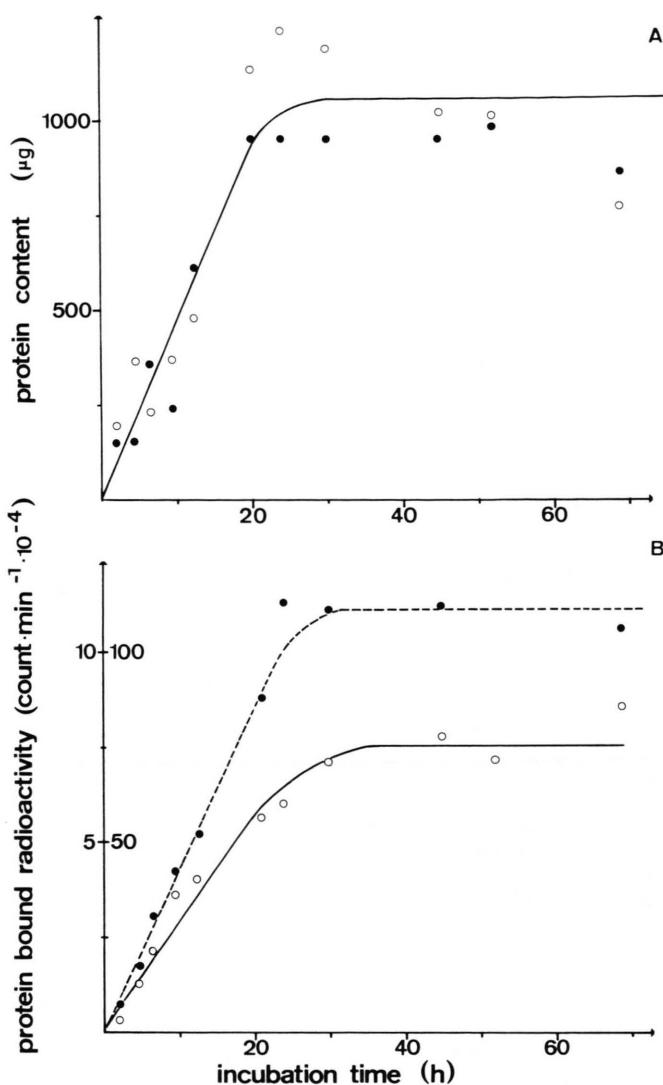


Fig. 1. Release of total protein (A) and protein-bound $[^3\text{H}]$ leucine (B) into the culture medium under normal (○) and hypertonic (●) growth conditions. Two spleens with 185 mg were grown in 4 ml of radioactive medium. At indicated times the protein content was measured in 0.1 ml aliquots of the medium. Protein-bound radioactivity was measured in 0.1 ml medium after precipitation with 100 μl of 10% trichloracetic acid, containing an excess of non-radioactive leucine, 2 washes with 5% trichloracetic acid and resolution of the protein in 0.5 ml 0.1 N NaOH for 1 h at 70 °C (single determinations).

Results

The release of protein and protein-bound $[^3\text{H}]$ leucine from mouse spleens into the medium

When mouse spleens were incubated in either isotonic or hypertonic serum-free medium they constantly released protein into the medium for a period of about 20–30 h (Fig. 1). Independent of the osmolarity, the protein released by 100 mg of spleen reached a final amount of about 1 mg of protein per 3 ml of incubation medium. In contrast, the total amount of protein-bound radioactive leucine

released into the hypertonic medium was only about 16% of that present in normal medium.

In six independent experiments hypertonic medium always resulted in a marked inhibition of $[^3\text{H}]$ leucine incorporation into spleen-associated, as well as into released proteins. Unexpectedly, at hypertonic conditions $[^3\text{H}]$ leucine incorporation was reduced to about 5% in spleen associated proteins but only to about 10% in the medium released proteins. This indicated that the synthesis of proteins which were released into the medium was less sensitive to high osmolarity than the synthesis of proteins that remained associated with spleen tissue.

Analysis of the radioactive proteins released into the medium

The proteins released from spleen cells into the medium were analyzed by SDS-gelelectrophoresis. When normal spleens had been incubated in isotonic medium, peaks of radioactivity were observed at positions corresponding to proteins with the MW of 60 000, 25 000, 12 000 and 7000 (Fig. 2a) as deduced from reference substances. Experiments with spleens from animals which had been inoculated with normal or scrapie brain homogenates, yielded almost identical electrophoresis patterns. However, the level of radioactivity at the 12 000 MW position in most experiments was higher in diseased animals.

Gel electrophoresis of radioactive proteins from hypertonic media revealed an almost complete inhibition of the ^3H -incorporation into the higher molecular weight proteins whereas the 12 000-molecular weight species was still synthesized (Fig. 2b). Thus the continued biosynthesis of spleen released proteins in hypertonic medium seems to be restricted to the 12 000 MW protein species.

Figure 2b shows furthermore that media from spleens of animals which had been inoculated with either normal or scrapie brain suspensions contain more radioactive 12 K protein than that of the control. No matter which medium had been taken, this protein did not change its position on the gel when either heating or mercapto-ethanol were omitted prior to the electrophoresis, indicating that disulfide linkages did not affect the molecular weight determination of this protein. Treatment of the tritiated protein with 10 μg of either trypsin, chymotrypsin or pronase for 1 h at 37 °C always resulted in conversion of the 12 000 dalton molecule into small fragments. When samples of [^{14}C]12 K protein obtained from normal spleens and [^3H]12 K protein from scrapie-infected spleens or vice versa were run on the same gel the radioactive material occupied exactly the same position indicating that we probably deal with the same protein in both cases.

After the detection of the 12 K protein in the incubation medium, we investigated spleen homogenates for the presence of this protein. We could detect only small amounts of 12 K protein in a sedimentable fraction obtained by high speed centrifugation (100 000 $\times g$ for 3 h) and hot extraction with a buffer containing SDS. In contrast to the amount of radioactivity incorporated into medium-released

12 K protein, only about 0.1% of the total protein-bound radioactivity was found as 12 K protein in the homogenate.

A protein with a molecular weight of about 11 600–11 800 [16, 17] known to be synthesized by lymphocytes [18–21], and which partly is released into the medium [20] is β -microglobulin. It was, therefore, attempted to precipitate 12 K protein with an antiserum directed against human β -microglobulin. Cross reactivity between human and murine β -microglobulin has been reported [22].

No preferential precipitation of 12 K protein with this serum was observed. 12 K protein and β -microglobulin, therefore, seem to be different proteins. An antiserum directed against mouse-interferon (generously supplied by Dr. J. Gresser, Institut de Recherches Scientifiques sur le Cancer, Villejuif, France) or against the immunoglobulin fraction of STU-mice also did not precipitate 12 K protein. Thus no antigenic relationship can be demonstrated between 12 K protein and these proteins.

Injection of labeled 12 K protein into mice

Since the 12 K protein is released or secreted from the spleen *in vitro* it is likely that this occurs also *in vivo*. We, therefore, injected into the tail vein of mice specifically labeled [^3H]12 K protein prepared using hypertonic medium. Radioactive proteins from isotonic medium, comprising all released proteins, served as controls. Animals were sacrificed 4 or 24 h after injection and the radioactivity in the various tissues was determined, after solubilization in Soluene 300 and decolorization with hydrogenperoxide.

The tritium levels detected 4 and 24 h after intravenous injection of either [^3H]12 K protein or total [^3H]protein are listed in Table I. Four hours after injection we find 630 dpm/0.1 ml of serum for [^3H]12 K protein. In comparison we can group the various organs into three categories. Group I such as red blood cells, muscle, heart, brain, eye, bone etc. contain definitely less radioactive 12 K protein than serum. Group II organs such as thymus, lymph-nodes, spleen, lung etc. contain about the same level as serum 4 or 24 h after injection. Group III organs contain definitely higher levels of [^3H]12 K protein after 4 h and even after 24 h. In this latter group we find kidney, liver, small intestine etc.

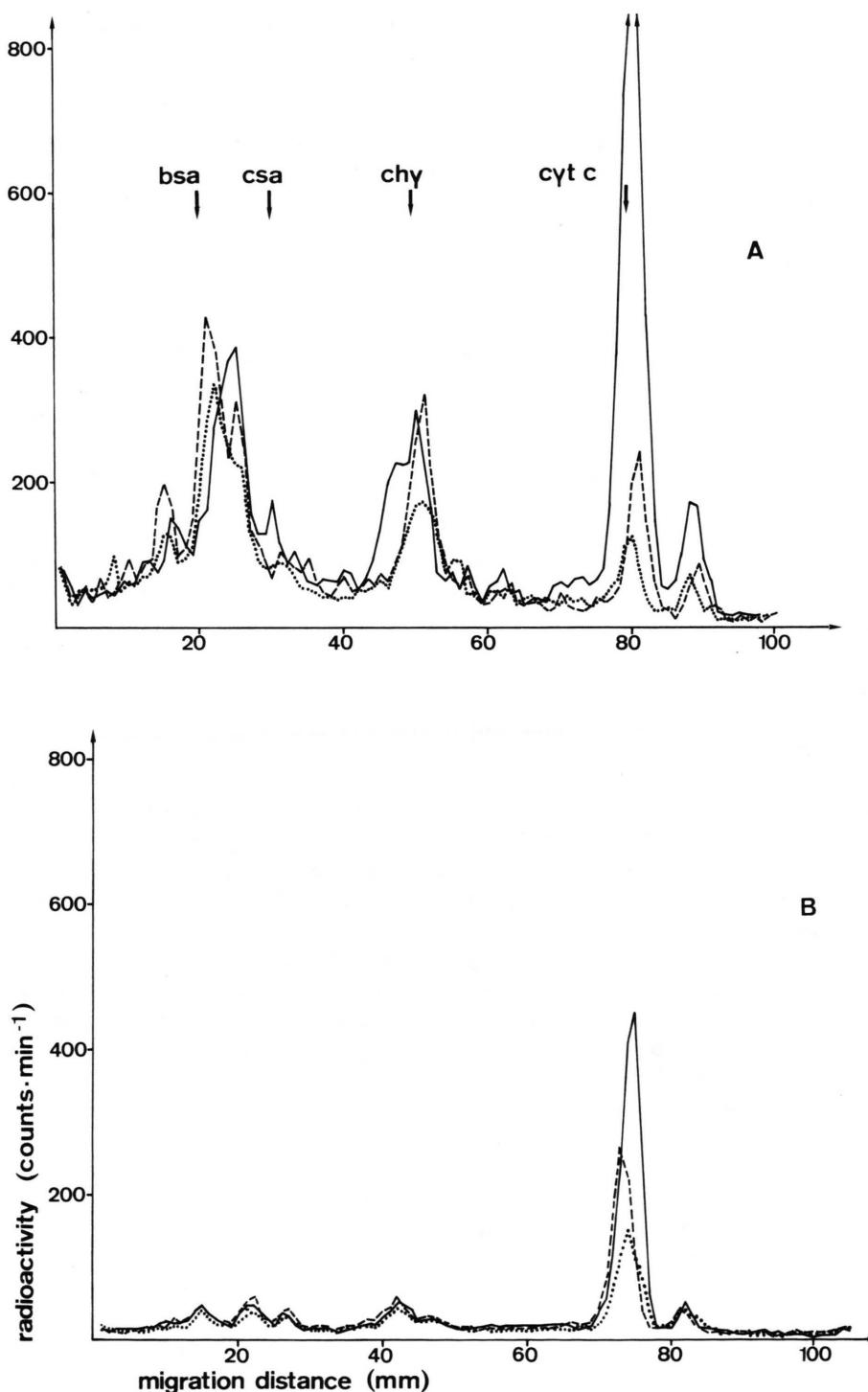


Fig. 2. SDS-gelelectrophoresis of radioactive proteins released into the medium during a 42 h incubation period. A) 25 μ l out of 10 ml high molecular weight fraction of an isotonic incubation. B) 50 μ l out of 10 ml of a hypertonic incubation. \cdots control, $-$ normal brain injection, $-$ scrapie brain injection. Arrows indicate positions of reference substances. Reference substances and their molecular weights bsa: bovine serum albumin 67 000, csa: Chicken serum albumin 45 000, ch: chymotrypsinogen 25 000, cyt c: cytochrome c 12 400.

Table I: Distribution of radiolabeled high molecular weight fraction proteins from media of cultured spleens in various mouse organs after intravenous infusion.

| Group | Tissue | 12 K protein ^a | | Total protein ^b | |
|-------|-------------------|---------------------------|----------------|----------------------------|------|
| | | 4 h ^d | 24 h | 4 h | 24 h |
| I | red blood cells | 50 | — ^e | — | — |
| | heart | 350 | 360 | 210 | 330 |
| | muscle | 160 | 280 | 100 | 140 |
| | oesophagus | 350 | 500 | 310 | 640 |
| | brain | 250 | 250 | 125 | 250 |
| | eye | 220 | 290 | 140 | 180 |
| | blood vessel wall | 280 | 400 | 250 | 270 |
| | bone | 260 | 370 | 160 | 260 |
| | skin | 60 | 120 | — | — |
| II | thymus | 280 | 620 | 200 | 340 |
| | lymphnodes | 330 | 420 | 290 | 380 |
| | serum | 630 | 480 | 640 | 600 |
| | spleen | 750 | 640 | 350 | 640 |
| | lung | 700 | 510 | 400 | 400 |
| | ovaries | 650 | 560 | 290 | 570 |
| | adrenal gland | 690 | 760 | 430 | 910 |
| | stomach | 820 | 750 | 400 | 600 |
| | rectum | 740 | 750 | 300 | 600 |
| III | colon | 1200 | 1500 | 340 | 710 |
| | small intestine | 1100 | 990 | 530 | 1000 |
| | liver | 1700 | 1000 | 600 | 830 |
| | kidney | 1100 | 780 | 620 | 740 |
| | salivary gland | 850 | 570 | 420 | 490 |

^a Salt independent proteins isolated from medium of spleens incubated at hypertonic conditions and labeled with [³H]leucine.

^b Proteins isolated from medium of spleens incubated under isotonic conditions and labeled with [³H]leucine.

^c Hours after injection of labeled material.

^d Mean values of two experiments. The deviation between the values was generally between 50 – 200 DPM.

^e Not determined.

contained more radioactive material than serum after 4 h.

Using the same experimental procedure as described for spleen we tested the synthesis of 12K protein in liver, kidney, salivary gland and lung (organs which had accumulated this protein) to determine if these organs themselves synthesize the protein. None of these organs synthesized and released 12K protein.

Discussion

Cultivation of mouse spleen under hypertonic medium conditions yields a specifically labeled protein species which is released into the medium. We assume that the 12K protein might be a protein with a yet unknown biological function. It cannot be a breakdown product of other proteins, since the synthesis of the other proteins is almost immediately shut off at the moment of changing the osmolarity of medium [2, 3]. It is rather unlikely that catabolism of various molecular species of radioactive high molecular weight proteins gives rise to a single radioactive protein. Furthermore, other organs cultivated did not produce and release 12K protein into the medium. The question then arises of whether this protein is a product of a latent murine virus. Considering that no murine virus is known to induce release of a single protein of 12000 daltons, this is rather unlikely. Moreover, we find 12K protein also in a different mouse strain (unpublished observations) obtained from a different breeder and housed in a different environment. Therefore, it seems to be likely that 12K protein is a protein originating from an as yet unidentified cell species of the spleen.

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When total ³H-labeled spleen released proteins were given to the animals and the levels of radioactivity in the various organs were compared with serum 4 h after injection, we found a group of organs that contained less radioactivity. This group coincided with group I of the [³H]12K protein experiments. We did not find, however, any organ that

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