were measured by the method of S. Piomelli [*Clin. Chim. Acta* **23**, 264 (1977)] after the sample was eluted into 0.3 ml of a solution containing 0.1 percent EDTA, 1 m*M* KCN, and 0.06 percent Sterox. The filter paper contained negligible amounts of lead and was precalibrated for sampling homogeneity (10.1 ± 0.5 μl of blood per quarter-inch disk).
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14. The results for the four Americans tested repeatedly suggest a decline in Pb-B by the end of the expedition followed by a return to the previous concentrations after 5 weeks, but are not statistically significant due to the small size of the sample.
15. The $\log_{10}$ average Pb-B concentration (micrograms per deciliter) was 0.531 ± 0.372 (N = 103); for 46 children, 0.544 ± 0.385; for 30 adult males, 0.580 ± 0.411; and for 27 adult females, 0.462 ± 0.278.
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22. The $\log_{10}$ average ferritin concentration (nanograms per milliliter) was 1.384 ± 0.359 (N = 107); for 47 children, 1.328 ± 0.360; for 30 adult males, 1.554 ± 0.313; and for 30 adult females, 1.281 ± 0.337.
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Endogenous Substrate for Cyclic AMP–Dependent Protein Kinase in Adrenocortical Polyadenylated Messenger Ribonucleoproteins

Abstract. *An endogenous polysomal cyclic AMP–dependent protein kinase specifically phosphorylates a 150,000-dalton peptide bound to an adrenocortical polyadenylated messenger ribonucleoprotein complex. There is a possibility that this protein is a physiological substrate of cyclic AMP–dependent protein kinase and that the phosphorylation and dephosphorylation of this substrate may be important in the translational control of adrenal polyadenylated messenger RNA.*

Investigations by various laboratories have indicated that protein phosphorylation is an important biological process that mediates several intracellular metabolic activities of eukaryotes (*1*). The phosphorylation reactions are catalyzed by cyclic nucleotide–dependent or cyclic nucleotide–independent protein kinases. Although we have recently provided evidence for the presence of an endogenous polysomal cyclic nucleotide–independent protein kinase that phosphorylates several adrenal proteins associated with polyadenylated messenger RNA [poly(A)mRNA] (*2*), there have been no reports so far of an endogenous protein kinase activated by adenosine 3′,5′-monophosphate (cyclic AMP) that is able to phosphorylate native poly(A)mRNA-associated protein [poly(A)mRNP] particles. Failure to demonstrate this phosphorylation with poly(A)mRNP particles was due to the technical problem of inactivation of protein kinase activity when poly(A)mRNP particles were isolated with conventional techniques of affinity chromatography followed by formamide elution and ethanol precipitation (*2*).

We recently described a technique for isolation of the polysomal particles that

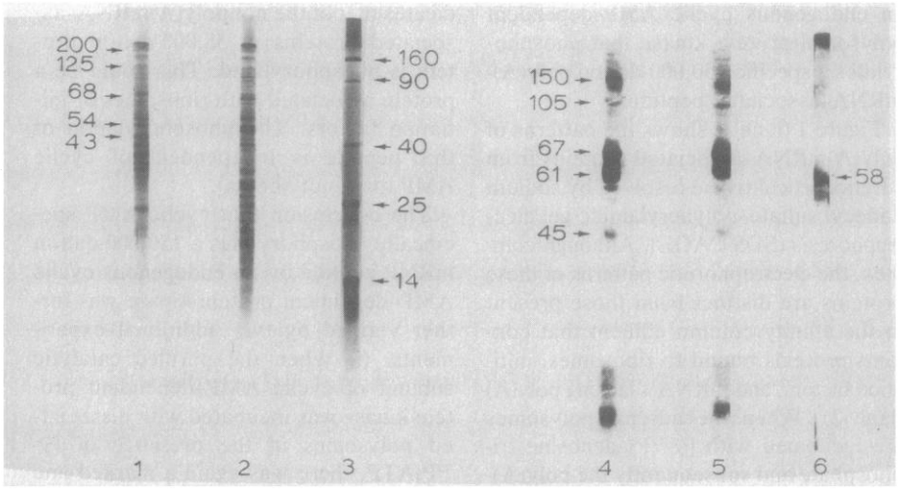

Fig. 1. Characterization of poly(A)mRNA-associated substrates of polysomal cyclic AMP-dependent protein kinases by sodium dodecyl sulfate–polyacrylamide gel electrophoresis. Total cytoplasmic polysomes were isolated from bovine adrenal cortex, dissociated in the presence of 1 m*M* puromycin dihydrochloride, and poly(A)mRNP particles were isolated by affinity chromatography on oligo-(dT)-cellulose (*2*). The Coomassie brilliant blue staining pattern of proteins after separation on 12.5 percent polyacrylamide gels (*9*, *10*) is depicted in lanes 1 to 3: (lane 1) poly(A)mRNA-bound proteins, (lane 2) affinity column effluent proteins, (lane 3) molecular weight markers (molecular weight × 1000). Protein kinase activity was assayed by incubation of puromycin-dissociated polysomes with [γ-^{32}P]ATP (28,000 Ci/mmole) prior to separation by affinity chromatography and gel electrophoresis. The ^{32}P incorporated was monitored by autoradiography of dried polyacrylamide gels with Kodak NS-2T x-ray film. Lanes 4 and 5 show the pattern of phosphorylated proteins bound to poly(A)mRNA's after incubation: (lane 4) in the absence and (lane 5) in the presence of the protein kinase inhibitor of cyclic AMP-dependent protein kinase. Lane 6 shows phosphorylated proteins present in the affinity column effluent.

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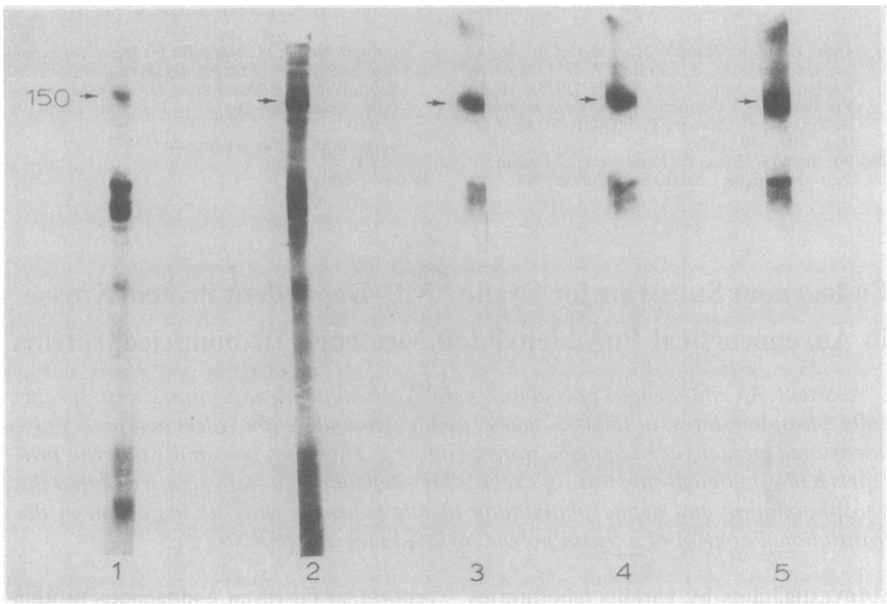

Fig. 2. Phosphorylation of one specific poly(A)mRNA-associated protein by polysomal cyclic AMP-dependent protein kinase. Conditions for protein kinase incubation, affinity chromatography, and polyacrylamide gel electrophoresis are identical with those in Fig. 1. Gels were treated with dimethyl sulfoxide and 2,5-diphenyloxazole (PPO) to enhance the sensitivity of the detection of radioactivity by fluorography (*11*) by exposure to Kodak RP Royal X-omat x-ray film at −70°C. Lanes 1 and 2 show poly(A)mRNA-associated phosphoproteins: (lane 1) phosphorylated by polysomal protein kinases, (lane 2) phosphorylated by the purified catalytic subunit of cyclic AMP-dependent protein kinase (*10*). The amount of catalytic subunit added in this experiment incorporates 14,000 dpm of ^{32}P from [γ-^{32}P]ATP into histone, as previously described (*10*). Lanes 3 to 5 depict poly(A)mRNA-associated phosphoproteins. The ^{32}P incorporated into proteins was detected by autoradiography as described in Fig. 1. (Lane 3) Puromycin-dissociated polysome incubated with [γ-^{32}P]ATP, (lane 4) same incubation in the presence of 10 μM cyclic AMP, (lane 5) same incubation in the presence of 100 μM cyclic AMP.

preserves the activity of the endogenous protein kinase (*2*). We now report the use of this methodology to demonstrate an endogenous cyclic AMP-dependent polysomal protein kinase that phosphorylates a specific 150,000-dalton poly(A)-mRNA-associated peptide.

Figure 1 (lane 1) shows the patterns of poly(A)mRNA-associated proteins from adrenocortical tissue resolved by sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE). Although complex, the electrophoretic patterns of these proteins are distinct from those present in the affinity column effluent that contains proteins bound to ribosomes, initiation factors, and mRNA's lacking poly(A) (lane 2). When the adrenal polysomes are incubated with [γ-^{32}P]adenosine triphosphate and subsequently the poly(A)-mRNP fractions are isolated, SDS-PAGE analysis by fluorography reveals that five poly(A)mRNA-associated proteins of 150,000, 105,000, 67,000, 61,000, and 45,000 daltons are endogenously phosphorylated. Lane 5 shows that only the phosphorylation of the 150,000-dalton peptide is reduced by cyclic AMP-dependent protein kinase inhibitor (*3*). This result indicates that endogenous cyclic AMP-dependent protein kinase specifically phosphorylates the 150,000-dalton peptide, whereas other peptides are phosphorylated by cyclic nucleotide-independent protein kinases. Lane 6 indicates that of the nonpoly(A)mRNA-associated proteins, a 58,000-dalton protein is phosphorylated. This could be a protein associated with ribosomes or initiation factors. The phosphorylation of this peptide is independent of cyclic AMP (data not shown).

The conclusion that cyclic AMP specifically phosphorylates a 150,000-dalton mRNP peptide by an endogenous cyclic AMP-dependent protein kinase was further verified by two additional experiments. (i) When the purified catalytic subunit of cyclic AMP-dependent protein kinase was incubated with dissociated polysomes in the presence of [γ-^{32}P]ATP, there was again a marked and specific increase of phosphate incorporation in the 150,000-dalton peptide [Fig. 2; compare lane 1 (control) with lane 2]. (ii) When increasing concentrations of cyclic AMP were incubated with puromycin-dissociated polysomes in the presence of [γ-^{32}P]ATP, a corresponding increase of the phosphorylated 150,000-dalton peptide was obtained.

We therefore conclude that the adrenal cortex polysomes contain an endogenous cyclic AMP-dependent protein kinase that, upon activation by cyclic AMP, phosphorylates a 150,000-dalton poly(A)mRNA-associated peptide as a specific substrate. This cyclic AMP-dependent phosphorylation is small and cannot be detected by the conventional filter assay used for the detection of kinase activity, as we have reported earlier (*2*). Even with the present sensitive fluorographic technique, we have found that a minimum absorbancy at 260 nm of 30 for the polysomes is necessary to isolate sufficient poly(A)mRNP complexes to detect phosphorylation of the 150,000-dalton peptide in vitro.

The physiological significance of cyclic AMP-dependent phosphorylation of the 150,000-dalton poly(A)mRNP-bound peptide is not known at this time. The maturation of mRNA's from initial transcription in the nucleus to final translation in the cytoplasm is a multistep process, and at each maturation stage RNA molecules form tight complexes with particular sets of proteins (*4*). Although this is the first demonstration of cyclic AMP-dependent protein kinase phosphorylation of an endogenous substrate that is bound to poly(A)mRNA, we and others have provided evidence for the phosphorylation of messenger ribonucleoprotein complexes by cyclic nucleotide-independent kinases (*2*, *5*). These kinases could conceivably play an important role in the translational control of the eukaryotic cell. Also adrenocorticotropic hormone is essential for the maintenance of adrenal cortex structure and function (*6*). Guanosine 3′,5′-monophosphate-dependent and cyclic AMP-dependent protein kinases are postulated to be the important regulators of hormonal signal (*7*). These nucleotide kinases could directly or indirectly affect the translation of a hypothetical preexistent mRNA (*8*) and thus control some of the functions of the adrenal cortex.

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Curvilinear Motion in the Absence of External Forces: Naïve Beliefs About the Motion of Objects

Abstract. *University students were asked to draw the path a moving object would follow in several different situations. Over half of the students, including many who had taken physics courses, evidenced striking misconceptions about the motion of objects. In particular, many students believed that even in the absence of external forces, objects would move in curved paths.*

In everyday life people constantly observe and interact with objects in motion. We might expect that, as a result of this extensive experience, people would develop a basic understanding of some of the fundamental principles of physics governing the behavior of moving objects. For example, we might expect them to know that objects move in straight lines in the absence of external forces and that falling objects accelerate.

Instruction is probably necessary to achieve an understanding of complex principles or to appreciate the details of fundamental laws (such as the fact that bodies in free fall on the earth undergo a constant acceleration of 9.8 m/sec^2). Furthermore, in some respects perceptual experience can be misleading. For instance, everyday experience suggests that objects set into motion eventually come to a stop when no obvious external force acts on them. Thus, it is not surprising that many people who lack formal instruction in physics do not grasp the principle of inertia (*1*).

Nevertheless, it seems that normal experience should be sufficient for a basic understanding of many simple mechanical principles. However, several experiments that we recently conducted with university students suggest that this is not the case. The experiments are part of a larger project that seeks to characterize internal representations of the physical world in people with various degrees of expertise in physics. The results clearly indicate that many students who have completed one or more physics courses, as well as many of those without formal instruction, fail to understand the most fundamental principles of mechanics. Furthermore, the data suggest that the students do not merely lack such knowledge; they espouse "laws of motion" that are at variance with formal physical laws.

In this report we describe the results of an experiment designed to assess understanding of the principle that objects move in straight lines in the absence of external forces. The subjects were 50 students enrolled in undergraduate courses at Johns Hopkins University. Three subjects failed to follow instructions. Of the remaining 47 subjects, 15 had taken no high school or college physics courses, 22 had completed one high school course, and 10 had completed at least one college physics course. Each subject was presented with 13 simple problems. Each problem consisted of a line drawing and instructions that explained the drawing and specified the subject's task. The drawings for the four problems discussed in this report are shown in Fig. 1.

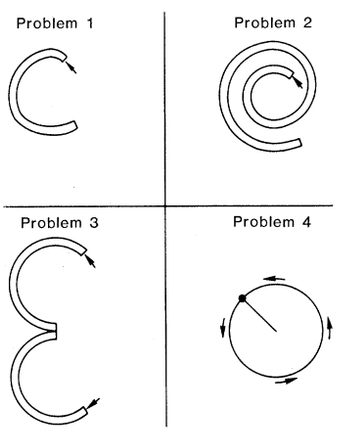

Fig. 1. Drawings for the four problems.

In problems 1 to 3, the subjects were instructed as follows:

> Each of the first several pages shows a thin curved metal tube. In the diagrams you are looking down on the tube. A metal ball is put into the end of the tube indicated by the arrow. The ball is then shot out of the other end of the tube at high speed. Your task is to draw the path the ball will follow after it comes out of the tube. . . . In drawing the path of the ball ignore air resistance. Assume that the ball will come out of the tube at the same speed for all of the tubes.

In problem 3, the subjects were also told that a ball is shot out of each of two tubes and that they should draw the paths of both balls.

In problem 4, the subjects were told:

> Imagine that someone has a metal ball attached to a string and is twirling it at high speed in a circle above his head. In this diagram you are looking down on the ball. The circle shows the path followed by the ball and the arrows show the direction in which it is moving. The line from the center of the circle to the ball is the string. Assume that when the ball is at the point shown in the diagram, the string breaks where it is attached to the ball. Draw the path the ball will follow after the string breaks. Ignore air resistance.

Many of the students clearly did not know that objects move in straight lines when no external force acts on them. Fully 36 percent of the pathways drawn were curved lines. More specifically, the paths were curved in 49 percent of the drawings by students with no formal physics instruction, 34 percent of the drawings by students who had taken one high school physics course, and 14 percent of the drawings by students who had completed one or more college courses.

Figure 2 presents the correct response and the most common erroneous responses to each of the four problems. Consider first the problems involving tubes (problems 1 to 3). For the simple C-shaped tube, one-third of the subjects drew a curved pathway for the ball (Fig. 2B). The results were even more striking for the spiral tube: half of the subjects drew curved lines. Of particular interest is the fact that for 19 of the 25 subjects who drew curved paths for at least one of the first two problems, the path drawn for the spiral tube (Fig. 2D) had a greater curvature than the path drawn for the C-shaped tube (Fig. 2B).

These results suggest that many people believe that when an object is passed through a curved tube, it will continue in curved motion even when no external forces act on it. Furthermore, some people believe that the more dra-

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