Characteristics of a Pyrimidine-specific 5'-Nucleotidase in Human Erythrocytes*

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A 5'-nucleotidase with unique specificity has been identified in the soluble fraction of normal human erythrocytes. It mediates the hydrolytic dephosphorylation of pyrimidine 5'-ribosenucleosidophosphates but is catalytically ineffective with pyrimidine nucleotides or with the 2', 3', or cyclic isomers of pyrimidine nucleotides. Activities at 37°C in dialyzed hemolysates of normal human erythrocytes averaged 7.3 and 6.2 μmol of P₃ liberated per hour per g of hemoglobin for the substrates UMP and CMP, respectively. Activity with TMP as substrate was approximately one-half as much as with UMP or CMP. Apparent Michaelis constants were 0.33 mM UMP, 0.15 mM CMP, and 1.0 mM TMP. Magnesium was required for optimal activity, and this cation could not be replaced by Mn²⁺. Maximum activity was obtained between pH 7.0 and 7.5 with rapid decreases in more alkaline media and moderate decreases with acidification.

The enzyme was quite sensitive to heat and was strongly inhibited by AMP, by some purine bases, and by both pyrimidine and pyrimidine nucleosides. Divalent cations of heavy metals were also strongly inhibitory, as were agents active against sulfhydryl groups. The presence of substrates and/or 2-mercaptoethanol provided considerable protection against some of these deleterious agents and conditions.

Pyrimidine 5'-nucleotidase activity in hemolysates was clearly distinguishable from erythrocyte acid phosphatase and from leukocyte and serum alkaline phosphatases and nucleotidases.

An unusual hereditary syndrome has been observed which includes, among other features, hemolytic anemia accompanied by pronounced basophilic stippling and markedly elevated erythrocyte nucleotides. The latter, initially presumed to represent ATP, ADP, and AMP (1, 2), were subsequently found to consist largely (>80%) of cytidine and uridine phosphates (3). Investigations undertaken to explain these remarkable accumulations of pyrimidine nucleotides revealed the normal existence of highly specific erythrocyte 5'-nucleotidase which was severely defective in patients with the syndrome (3). This enzyme catalyzes the hydrolytic dephosphorylation of pyrimidine 5'-nucleotides but not purine nucleotides or a variety of related analogs. While 5'-nucleotidases (5'-ribonucleotide phosphohydrolase, EC 3.1.3.5) are ubiquitous (4-6), they classically react with a broad spectrum of nucleoside monophosphates and are catalytically ineffective with purine nucleotides or with the 2', 3', or cyclic isomers of pyrimidine nucleotides. Activities at 37°C in dialyzed hemolysates of normal human erythrocytes averaged 7.3 and 6.2 μmol of P₃ liberated per hour per g of hemoglobin for the substrates UMP and CMP, respectively. Activity with TMP as substrate was approximately one-half as much as with UMP or CMP. Apparent Michaelis constants were 0.33 mM UMP, 0.15 mM CMP, and 1.0 mM TMP. Magnesium was required for optimal activity, and this cation could not be replaced by Mn²⁺. Maximum activity was obtained between pH 7.0 and 7.5 with rapid decreases in more alkaline media and moderate decreases with acidification.

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were filtered and assayed for $P_i$ by the method of Fiske and SubbaRow (14). One unit of nucleotidase activity was defined as the amount of enzyme catalyzing the release of 1 μmol of $P_i$ per hour per g of hemoglobin.

RESULTS

Preliminary experiments established that $P_i$ release during incubation was dependent upon both an appropriate pyrimidine substrate and undegraded hemolysate. Denaturation by heat or acidification rendered hemolysates totally inactive. Observed nucleotidase activities were consistently a linear function of both hemolysate concentration and of incubation time up to 4 hours (Fig. 1). Destromatization of dialyzed hemolysates by high speed centrifugation did not diminish activity of the supernatants, nor was there perceptible activity in reconstituted stromata.

Reagent blanks uniformly exhibited less than 10% of total activities if hemolysates were dialyzed free of endogenous nucleotides and other phosphates prior to assay. Comparative studies had previously shown no diminution in nucleotidase activity secondary to the dialysis procedure per se (3).

Inclusion of the sulphydryl reagent, 2-mercaptoethanol, in the incubation mixture was noted to increase nucleotidase activities by approximately 20% at concentrations between 0.2 and 1.5 mM. The standard assay system eventually incorporated 2-mercaptoethanol at a final concentration of 0.4 mM. Comparable levels of glutathione also resulted in activation, but cysteine was without perceptible effect until its concentration exceeded 1 mM. Ascorbic acid, an activator of serum 5'-nucleotidase, produced no observable effect even at a final concentration of 10 mM.

Normal Values for Pyrimidine 5'-Nucleotidase—Measurements of erythrocyte nucleotidase activities with either UMP or CMP as substrate were performed on hematologically normal individuals and on patients with various levels of reticulocytosis induced by causes other than demonstrable erythroenzymopathies. Table I records mean values for these assays. Enzymatic activities were approximately 20% less when CMP was the substrate rather than UMP, regardless of the presence of reticulocytosis. Reticulocytosis was accompanied by a general increase in reaction rates, but there was no close correlation between activity and percentage of reticulocytes in this small group.

Substrate Specificity—Numerous preliminary experiments indicated that AMP was not a substrate for erythrocyte 5'-nucleotidase under the conditions of this assay. Values for $P_i$ evolution from AMP were virtually identical with those from reagent blanks. In studies with 10 different hemolysates, the mean $A_{460}$ of comparable aliquots of the $P_i$ colorimetric solution was 0.026 (range = 0.014 to 0.032) in systems incubated with 0.23 to 2.3 mM AMP. Corresponding values from 20 reagent blanks assessed simultaneously ranged between 0.014 and 0.033, averaging 0.024. These means were less than 10% of the values obtained with 2.3 mM UMP or CMP.

The 5'-monophosphates of inosine, guanosine, and xanthosine and the 3'-monophosphate of adenosine were similarly ineffective substrates at 2.3 mM final concentrations, also yielding less than 10% of the $P_i$ evolved from identical systems containing either UMP or CMP. In one experiment, adenosine 2'-monophosphate yielded 20% as much $P_i$ as UMP or CMP.

Among pyrimidine analogs, cytidine 3'-monophosphate was totally ineffective as a substrate, but the cyclic 2':3'-monophosphate on one occasion yielded almost one-third as much $P_i$ as did CMP. The 2'-deoxyribose analogs, deoxyuridine 5'-phosphate and deoxythymidine 5'-phosphate, were utilized almost as effectively as UMP and CMP at comparable concentrations.

Effects of Substrate Concentration—The substrate concentration (2.3 mM) selected for a standard assay system was found consistently to yield nucleotidase activities which were within ±5% of those obtained at twice that concentration. The maximum reaction velocity attainable with CMP was consistently about 80 to 85% of that obtained with UMP, whether or not the system contained 2-mercaptoethanol (Table I). At comparable concentrations, TMP was approximately 50% as effective a substrate as UMP.

Activities were determined with UMP or CMP at various concentrations between 0.23 and 4.6 mM. Although reaction rate curves appeared hyperbolic, sigmoidal kinetics could not be ruled out, since substrate availability may vary considerably at the lower concentrations during such long incubations, making reaction velocity measurements unreliable in this region. Average values from such studies are presented as Wolff plots in Fig. 2, demonstrating an approximately 2 fold difference between apparent $K_m$ (UMP) and $K_m$ (CMP). Twelve separate determinations on hemolysates from 6 normal subjects yielded mean values for apparent $K_m$ of 0.33 μM UMP (range = 0.25 to 0.39 mM) ($V_{max}$ = 9.3 units) and 0.15 μM CMP.

### Table I

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Pyrimidine 5'-nucleotidase activity</th>
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<tbody>
<tr>
<td></td>
<td>UMP</td>
</tr>
<tr>
<td></td>
<td>μmol $P_i$/hr/g hemoglobin (± S.D.)</td>
</tr>
<tr>
<td>No additive</td>
<td>MCE added</td>
</tr>
<tr>
<td>Normal controls</td>
<td>6.6 ± 2.0</td>
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<tr>
<td>(n = 116)</td>
<td>(n = 50)</td>
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<tr>
<td>Reticulocytosis*</td>
<td>14.1 ± 6.0</td>
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<tr>
<td>(n = 24)</td>
<td>(n = 9)</td>
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</table>

* Mercaptoethanol.
* Range of reticulocytosis = 2.4 to 36.0%.
(range = 0.13 to 0.18 mM) \( (V_{\text{max}} = 6.9 \text{ units}) \). Two determinations with TMP as variable substrate yielded a \( K_m \) value of 1.0 mM \( (V_{\text{max}} = 3.9 \text{ units}) \). Addition of mercaptoethanol to the assay system did not alter apparent \( K_m \) (UMP) or \( K_m \) (CMP), despite its effect on \( V_{\text{max}} \).

**Effect of pH**—Under conditions of the standard assay system, nucleotidase activity peaked distinctly between pH 7.0 and 7.5 rather than exhibiting the broad flat curve noted in our preliminary studies (3). Fig. 3 shows curves obtained with UMP and CMP compared to those obtained with the acid and alkaline phosphatase substrates, \( \alpha \)-, and \( \beta \)-glycerophosphate.

The rapid decline of activity in more alkaline media is quite different from that observed with nucleotidases in serum (15, 16) and diverse other tissues (8, 10, 17, 19). Higher and more consistent values for erythrocyte nucleotidase activities might be expected if the pH of the incubation medium were lowered from pH 7.8 to approximately 7.4.

**Inhibition by Purine and Pyrimidine Compounds**—Although AMP was not utilizable as a substrate, it did interfere with the dephosphorylation of UMP or CMP. As shown in Fig. 4, this interference was concentration-dependent and was more pronounced if the nucleoside or purine base, rather than the nucleotide, was present during incubation. Adenosine produced an inhibition curve which was virtually identical with that resulting from its deaminated analog, inosine.

Relative inhibitory effects of these and other nucleosides, nucleotides, and free bases are presented in Fig. 5. Nucleosides in general, both purine and pyrimidine, were consistently inhibitory to varying degrees. Strong inhibition by guanosine was comparable to that by adenosine or inosine, yet the phosphorylated purine nucleosides, except AMP, had little or no effect on nucleotidase activity. Among the bases, guanine was as strongly inhibitory as adenine, but hypoxanthine, xanthine, and the pyrimidine bases were without perceptible effects. The presence of free ribose or ribose-5-phosphate did not significantly alter observed nucleotidase activities.

Inhibitory effects of adenine and AMP were completely abolished by redialysis. Dialyzed hemolysates were incubated for 20 min at 37\(^\circ\) with 2.3 mM adenine, adenosine or AMP, then redialyzed for 45 min at 4\(^\circ\) against 250 volumes of 0.01 M Tris, pH 8.0, containing 10 mM MgCl\(_2\), 0.02 mM EDTA, and 0.5 mM 2-mercaptoethanol. These were redialyzed a second time against 250 volumes of the same medium for an additional 45 to 90 min prior to assaying for nucleotidase activity. Results of duplicate experiments with two different cell samples assayed...
in quadruplicate indicated that 102 to 105% of the original activity was present in systems incubated with adenine or AMP prior to redialysis. Those incubated with adenosine, however, retained only 52 to 82% of control activities, averaging 71%.

Effects of Sulphydryl Inhibitors—Nucleotidase activity was 50% inhibited by p-chloromercuribenzoate or N-ethylmaleimide at approximately 0.1 mM concentrations, but inhibition was less pronounced with CMP as the substrate than it was with UMP. Mercaptoethanol largely abolished the inhibitory effects of both reagents at this concentration. The enzyme was relatively insensitive to iodoacetate, which reduced activity by only 10 to 15% at a final concentration of 1 mM.

Effects of Metal Cations—As shown in Fig. 6, nucleotidase activity was dependent upon Mg$^{2+}$ concentration. Hemolysates dialyzed thoroughly against the Tris buffer devoid of MgCl$_2$ or EDTA exhibited optimum activity only when Mg$^{2+}$ was added to final concentrations of 1 mM or more. Manganese could not replace Mg$^{2+}$ as an activator and in fact was inhibitory. Some enzyme instability was apparent under these dialysis conditions as well, since the maximum activity obtained (approximately 5.0 units) was slightly less than that usually observed with hemolysates dialyzed in the presence of MgCl$_2$ and EDTA.

Alterations of nucleotidase activities induced by other metal cations at final concentrations between $10^{-4}$ and $10^{-3}$ M fell into four general categories (Table III). Trivalent chromium distinctly stimulated activity; some cations (Ni$^{2+}$ and Ba$^{2+}$) were without significant effect; and others were moderately (Zn$^{2+}$ and Mn$^{2+}$) or markedly (Cu$^{2+}$, Pb$^{2+}$, Hg$^{2+}$, and Cd$^{2+}$) inhibitory. When CMP rather than UMP was the substrate, both inhibitory and stimulatory effects of these cations were generally less pronounced. With either substrate, relative stimulation was increased and relative inhibition was decreased by the presence of mercaptoethanol. For example, with UMP as substrate, 0.4 mM mercaptoethanol increased nucleotidase activity in the presence of 1 mM Cr$^{3+}$ from 123% to 139% of initial activity. The ability of mercaptoethanol to reduce enzymatic inhibition by Cd$^{2+}$ and Cu$^{2+}$ was less pronounced but readily apparent and consistent.

Heat Stability—Pyrimidine 5'-nucleotidase activity in dialyzed hemolysates was markedly sensitive to thermal inactivation. Preliminary screening studies indicated that activity was completely lost after 5 min at 100°. Residual activities following incubation at 60° for 10 min or 50° for 30 min were 0 to 8% of initial activities. Fig. 7A demonstrates the rapid deterioration of activity induced by hemolysate incubation at 45°. These experiments were performed before mercaptoethanol was a standard component of the assay system. In three separate experiments, however, addition of mercaptoethanol to the hemolysate to a final concentration of 0.4 mM either before, during, or after heat exposure did not appreciably alter the results.

Significant protection against thermal inactivation was afforded by the presence of substrate during the period of heat exposure. Observed nucleotidase activities in hemolysates protected by CMP were essentially identical, whether subsequently measured with UMP or CMP as substrate, perhaps reflecting the lower $K_m$ for CMP carried over from the initial incubation. As shown in Fig. 7A, resistance to thermal inactivation was significantly enhanced by the presence of the pyrimidine substrate (CMP) and to some extent as well by the purine analog (AMP). The true effect of AMP on thermal sensitivity under these conditions is probably masked by the fact that AMP was also carried over into the assay mixture and did not replace Mg$^{2+}$ as an activator and in fact was inhibitory. Some enzyme instability was apparent under these dialysis conditions as well, since the maximum activity obtained (approximately 5.0 units) was slightly less than that usually observed with hemolysates dialyzed in the presence of MgCl$_2$ and EDTA.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Cation</th>
<th>UMP</th>
<th>CMP</th>
<th>UMP</th>
<th>CMP</th>
<th>UMP</th>
<th>CMP</th>
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<tbody>
<tr>
<td>Activation</td>
<td>Cr$^{3+}$</td>
<td>100</td>
<td>102</td>
<td>111</td>
<td>106</td>
<td>112</td>
<td>100</td>
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<tr>
<td>Minimal or no inhibition</td>
<td>Ni$^{2+}$</td>
<td>89</td>
<td>93</td>
<td>91</td>
<td>92</td>
<td>75</td>
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<td>Ba$^{2+}$</td>
<td>93</td>
<td>102</td>
<td>102</td>
<td>111</td>
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<tr>
<td>Moderate inhibition</td>
<td>Mn$^{2+}$</td>
<td>95</td>
<td>95</td>
<td>59</td>
<td>63</td>
<td>32</td>
<td>29</td>
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<tr>
<td></td>
<td>Zn$^{2+}$</td>
<td>87</td>
<td>91</td>
<td>26</td>
<td>23</td>
<td>21</td>
<td>17</td>
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<tr>
<td>Masked inhibition</td>
<td>Cu$^{2+}$</td>
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<td>94</td>
<td>45</td>
<td>64</td>
<td>7</td>
<td>12</td>
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<tr>
<td></td>
<td>Hg$^{2+}$</td>
<td>84</td>
<td>93</td>
<td>20</td>
<td>35</td>
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Fig. 6. Representative experiment demonstrating effect of Mg$^{2+}$ concentration on erythrocyte nucleotidase activity. Hemolysate was prepared by the usual procedure, but the dialysis medium and buffer were devoid of Mg$^{2+}$ or EDTA. Mercaptoethanol (0.4 mM) was present in the assay system. Nucleotidase activity was completely lost after 5 min at 100°. Residual activities following incubation at 60° for 10 min or 50° for 30 min were 0 to 8% of initial activities. Fig. 7A demonstrates the rapid deterioration of activity induced by hemolysate incubation at 45°. These experiments were performed before mercaptoethanol was a standard component of the assay system. In three separate experiments, however, addition of mercaptoethanol to the hemolysate to a final concentration of 0.4 mM either before, during, or after heat exposure did not appreciably alter the results.

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UMP or CMP as substrate. Reagent blanks consisted of identical appropriate periods, were inactivated by heating quickly to 60° for mixtures of hemolysate and stabilizer, which, after exposure to 45° for appropriate periods, were inactivated by heating quickly to 60° for 10 min. These were cooled rapidly to 37° for the incubation phase of the assay. Each point is the mean value of 6 to 10 determinations on four normal hemolysates. The shaded area encompasses two standard deviations on either side of mean nucleotidase activities in eight unprotected hemolysates assayed at the same time intervals. B, effects of mercaptoethanol and substrates in protection of erythrocyte nucleotidase against deterioration at 37°. The control curve depicts the mean decay rate for nucleotidase activity in crude unprotected hemolysates exposed to 37° for the periods indicated prior to the addition of substrate for the incubation phase of the assay procedure. Points on the control curve are means of 4 to 10 determinations on three hemolysates. Points on the remaining curves are means of two to three assays on the same hemolysates, containing 1.1 mM UMP, 1.1 mM CMP, or 0.4 mM mercaptoethanol (MCE) during exposure to 37° prior to assaying nucleotidase activities.

FIG. 8 (right). Deterioration of erythrocyte nucleotidase activity as a consequence of hemolysate storage at -20°. Hemolysates were frozen after overnight dialysis in the usual manner except the dialysis medium, 0.05 M Tris, pH 8.0, was devoid of MgCl₂ or EDTA. Each point is the mean of two to five assays on three separate specimens from 2 normal subjects. Broken lines indicate values obtained with mercaptoethanol (MCE) in the assay system.

DISCUSSION

It has been known for over one-half a century that certain enzymes in mammalian tissues hydrolytically dephosphorylate nucleic acid derivatives (4, 20, 21). Some act selectively on nucleoside 5'-monophosphates (5, 22). Such 5'-nucleotidases are distinguishable from nonspecific acid or alkaline phosphatases by sharp differences in cation requirements, in activities as a function of pH, and in responses to certain activators and inhibitors (6, 9, 10, 12, 15-19, 29). Whether obtained from diverse mammalian tissue extracts or secretions, these enzymes are catalytically active with a broad range of substrates, including both purine and pyrimidine 5'-ribonucleotides, but not the 2'-, 3',- or cyclic isomers (4, 5, 7-12).

Nucleosidases are known which cleave ribose from specific purine or pyrimidine bases (24), but there is apparently no such substrate selectivity among nucleotidases previously studied. In their studies with aqueous extracts of canine kidney and intestinal mucosa, Levene and Medigreceanu (4) noted that enzymatic hydrolysis of purine nucleotides proceeded more rapidly than hydrolysis of pyrimidine nucleotides. Conversely, it has also been observed that nucleotidase from some sources, such as bovine seminal plasma, may exhibit higher optimum activities with pyrimidine rather than with purine nucleotides (10). In all instances, however, the individual nucleotidase actively dephosphorylated either class of substrates.

It seems quite probable that the "UMPase" activity detected in soluble fractions of erythrocytes by Boninsegna et al. (25) was the same pyrimidine 5'-nucleotidase described herein. This remains uncertain, however, since their experiments were directed toward another purpose and did not include substrates other than uridine compounds. In any case, the present studies indicate that a pyrimidine-specific 5'-nucleotidase does exist within mature human erythrocytes. Indeed, their normal maturation and survival apparently is heavily dependent upon the proper function of this enzyme, since its hereditary deficiency is associated with premature hemolysis (3).

The erythrocyte enzyme was clearly distinguishable from human serum and other tissue nucleotidases or phosphatases by a number of criteria. In crude or dialyzed hemolysates, nucleotidase activity was exclusively limited to UMP, dUMP, CMP, dCMP, and TMP, in descending order of effectiveness.

![Graph](http://www.jbc.org/)

Fig. 7 (left and center). A, substrate protection of erythrocyte pyrimidine nucleotidase against thermal inactivation at 45°. Either CMP or AMP was added to hemolysate to a final concentration of 3.3 mM. Hemolysates were heated to 45° for the periods indicated, rapidly cooled, then assayed for nucleotidase activity using the standard assay system with UMP or CMP as substrate. Reagent blanks consisted of identical mixtures of hemolysate and stabilizer, which, after exposure to 45° for appropriate periods, were inactivated by heating quickly to 60° for 10 min. These were cooled rapidly to 37° for the incubation phase of the assay. Each point is the mean value of 6 to 10 determinations on four normal hemolysates. The shaded area encompasses two standard deviations on either side of mean nucleotidase activities in eight unprotected hemolysates assayed at the same time intervals. B, effects of mercaptoethanol and substrates in protection of erythrocyte nucleotidase against deterioration at 37°. The control curve depicts the mean decay rate for nucleotidase activity in crude unprotected hemolysates exposed to 37° for the periods indicated prior to the addition of substrate for the incubation phase of the assay procedure. Points on the control curve are means of 4 to 10 determinations on three hemolysates. Points on the remaining curves are means of two to three assays on the same hemolysates, containing 1.1 mM UMP, 1.1 mM CMP, or 0.4 mM mercaptoethanol (MCE) during exposure to 37° prior to assaying nucleotidase activities.
Purine nucleotides, 2', 3', and cyclic pyrimidine ribosemono-
phosphates, and compounds commonly used as substrates for
nonspecific phosphatase were not catalytically dephos-
phorylated under these conditions. The restriction to pyrimi-
dine substrates demonstrated by these in vitro studies appar-
ently extends to the physiologic role of erythrocyte nucleotid-
ase. This may be inferred from one of the consequences of
severe hereditary deficiency of this enzyme, specifically the 3- to 6-fold elevations in total intracellular nucleotide concen-
trations (3). These consisted largely (>80%) of cytidine and
uridine phosphates. Adenine nucleotide concentrations were
actually decreased below those expected for cells of comparable
ages, and guanine nucleotides were not detectable. These
compounds presumably represent degradation products of
RNA derived during reticulocyte maturation, and relative
accumulations of all four would be expected in hereditary
deficiency states if the erythrocyte enzyme were catalytically
effective with both purine and pyrimidine 5'-nucleotides in
vivo.

Apparent Michaelis constants for UMP were identical with the
K_m (AMP) reported for human serum (16), but were 10
times greater than those reported for partially purified nucleotid-
ase from human liver (9). As with nucleotidases from most
tissues, the erythrocyte enzyme required Mg^{2+} for optimum
activity, but it was inhibited by Mn^{2+}, a cation which may
activate the nucleotidases of human liver (9), aorta (25), and
serum (26). Activity variations as a function of pH differed
entirely from those characteristic of erythrocyte acid phosph-
ate or nonspecific alkaline phosphatase possibly intro-
duced by contaminating leukocytes. Furthermore, there was no
evidence of the double pH optimum of the hepatic enzyme
induced by Mg^{2+} (9) nor of the relative insensitivity to alkaline
pH usually exhibited by serum nucleotidases (15, 16, 18).
Distinction from red cell acid phosphatase is emphasized by
our previous observation that individuals hereditarily deficient
in erythrocyte nucleotidase nonetheless have abundant phos-
phatase activities (3).

The enzyme in dialyzed hemolysates was highly susceptible
to inactivation by a variety of agents and conditions, especially
those affecting sulfhydryl groups. Nucleotidase activity was
rapidly lost following exposure to certain heavy metals, organic
sulfhydryl reagents, and elevated temperatures. Considerable
protection against such inactivation was afforded by 2-mercap-
toethanol, by pyrimidine substrates, and perhaps by some
other purine nucleotides as well.

It would be premature to attempt descriptions of the enzyme
combining site based on studies with unpurified enzyme, yet
several preliminary observations merit attention in this regard.
Agents or conditions which either inhibited or stimulated
nucleotidase activity (e.g. exposure to N-ethylmaleimide or to
trivalent chromium ions, respectively) consistently produced
greater relative effects when UMP was the substrate rather
than CMP. This observation, coupled with the enzyme's lower
V_max and apparent K_m for CMP and the inhibitory effects of
several nucleosides and free bases, suggests that the pyrimi-
dine moiety itself (and probably the ribose) is intimately
involved in the enzyme-substrate coupling mechanism. Such a
conclusion is supported a priori by the clear exclusion of
nonpyrimidine nucleotides as substrates. The existence of
distinct combining sites for UMP as opposed to CMP seems
improbable, since preliminary experiments to determine inhib-
tion constants for AMP and other purine and pyrimidine
compounds indicate that competitive inhibition is involved.

Evolution of a nucleotidase with such unique specificity
might be expected teleologically to occur in human erythro-
cytes. These cells lack the metabolic sophistication and
redundancy of nucleated cells and must rely almost exclusively
on anaerobic glycolysis to generate high energy phosphates in
the form of ATP. Since they are not capable of de novo
nucleotide synthesis, they must carefully preserve their ade-
nine nucleotide pool against irrecoverable loss. In this regard,
AMP is in a specific position of jeopardy, for AMP deaminase
is quite active in mammalian erythrocytes, and enzymatic
systems to reverse or counter this reaction do not exist.
Furthermore, adenosine may be irreversibly deaminated to
inosine. In the absence of compensatory mechanisms, there-
fore, a nucleotidase which acted actively on AMP could be
expected eventually to deplete the adenine nucleotide pool.
Yet, maturing reticulocytes apparently require a nucleotidase
to render diffusible uridine and cytidine phosphates resulting
from degradation of RNA. These compounds were observed
to accumulate in large amounts in those cells with hereditarily
defective nucleotidase (3) and may seriously interfere with
certain enzymes which are critical to erythrocyte glycolysis,
such as pyruvate and phosphoglycerate kinases. Evolution of a
pyrimidine-specific 5'-nucleotidase thus appears to represent
another instance of erythrocyte adaptation to unique metabolic
restrictions.

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