The Bacterial Ribonucleic Acid (RNA)

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ABSTRACT: This article discusses the bacterial RNA cycle in soil from the perspective of persistence of extracellular RNA in soil and RNA as a nutrient source for other microorganisms.

KEYWORDS: RNA nucleic acid, cycles, microorganisms, nutrient, persistence, soil

INTRODUCTION
What happens to RNA (ribonucleic acid) when a bacterial cell dies and releases it’s cellular contents into the soil environment? Do extracellular RNases degrade it? Do other microorganisms use the RNA as a nutrient source? We will discuss these questions in this paper.

The major role of RNA in the bacterial cell is protein synthesis, and the site of protein synthesis is the ribosome. The bacterial ribosome is composed of two subunits, the 30S (Svedberg units) and 50S. Each subunit contains proteins and specific ribosomal RNAs (rRNA). The bacterial 30S subunit contains approximately 21 proteins and 16S rRNA, while the bacterial 50S subunit contains a 5S and 23S rRNA and about 34 proteins. Transfer RNA (tRNA) brings the individual amino acids to the ribosome where the messenger RNA (mRNA) sequence is translated into a protein sequence. Protein synthesis at the ribosomal site follows four steps, initiation, elongation, termination-release and polypeptide folding (Madigan et al., 1997).

Of the three RNAs, tRNA and rRNA are the most stable. However, they are not as stable as chromosomal DNA and are replaced during the lifetime of a bacterial cell. Messenger RNA has a half-life measured in minutes. Transfer RNA and ribosomal RNA account for 90-95% of the total amount of RNA in the bacterial cell, the remainder being mRNA (Kjeldgaard 1967). The cellular content of RNA is closely tied to the growth and physiology of the bacterial cell.

RNA CYCLING IN SOIL
Persistence of extracellular RNA

When a bacterium in soil lyses, what happens to the RNA? Does it degrade or can RNA persist outside the bacterial cell? There has been some research on the persistence of extracellular DNA in soil but little is known about RNA. DNA and RNA are similar in that both possess a negative charge and both are composed of nucleotides, differing only in the sugar and one base. DNA is double stranded while RNA is single. Despite these minor differences, factors affecting persistence in soil could be the same for both macromolecules.

In general, nucleic acids (RNA and DNA) released from dead cells are quickly digested by RNases and DNases, respectively, in soil, sediment and aquatic environments (Greaves and Wilson, 1970; Novitzky, 1986; Paul et al., 1989; Romanowski et al., 1992, 1993). However, various studies have shown that DNA, and most likely RNA, do persist in the soil environment for varying lengths of time (Greaves and Wilson, 1970; Recorbet et al., 1993; Romanowski et al., 1992, 1993). Extracellular DNA can form complexes with soil particles (Lorenz and Wackernagel, 1994) protecting it from enzymatic degradation. An anionic polymer, which could be DNA or RNA, will adsorb to negatively charged soil and sediment particles via cation bridging. Results from experiments by Demanèche et al. (2001) suggested that nucleases also become bound to clay particles, separating the DNA and enzymes physically so that the nucleases cannot degrade the DNA. If the sites on the clay particles become saturated with nucleases then the DNA is no longer protected.
Numerous factors affect the rate and extent of adsorption of nucleic acids, and in turn may affect the persistence of DNA and RNA. These factors include the pH of the bulk phase, valence and concentration of cations and type of mineral in the soil (Lorenz and Wackernagel, 1994). The capacity of various soil minerals to adsorb DNA varies. Lorenz and Wackernagel (1992) reported that although bentonite clay made up only 0.6% (wt/wt) of the mineral material in a sand-clay microcosm, 60% of the DNA was adsorbed to the bentonite. Research has shown that adsorption of nucleic acids to soil particles increases with decreasing pH (Greaves and Wilson, 1969; Ogram et al., 1988; Romanowski et al., 1991; Khanna and Stotzky, 1992). As the pH decreases, nucleic acids take on a more positive charge due to protonation of the bases facilitating adsorption onto soil particles (Greaves and Wilson, 1969). Divalent cations have been reported to increase the adsorption of nucleic acids to montmorillonite and sand more than monovalent cations (Greaves and Wilson, 1969; Lorenz and Wackernagel, 1987; Romanowski et al., 1991; Paget et al., 1992). In addition, increasing the concentration of cations has been observed to increase adsorption (Lorenz and Wackernagel, 1987; Romanowski et al., 1991; Paget et al., 1992). Cations, whether mono-, di-, or multivalent, act as cationic or positively charged bridges between the anionic or negatively charged nucleic acids and soil particles (Theng, 1979; Hesselink, 1983).

Is there any evidence that RNA persists in the environment? Extracellular RNA has been found in concentrations of 6.67 to 192.8 µg/l in coastal and estuarine waters and 4.03 to 13.9 µg/l in open ocean waters (Karl and Bailiff, 1989).

**RNA as a nutrient source in soil**

The presence of naked or extracellular bacterial RNA in soil originates from bacterial cells upon lysis and death. Bacterial ribosomal and transfer RNA may be present in higher concentrations in soil than messenger RNA due to the higher concentration of the former in the cell. As mentioned previously, extracellular nucleases often digest naked RNA producing short oligonucleotides. The oligonucleotides can undergo hydrolysis by nucleoside-catabolizing enzymes to yield nucleosides that are actively transported across the bacterial cell membrane into the cells (Stewart and Carlson, 1986).

Most bacteria can synthesize their own nucleotides; thus, what is the reason they transport nucleosides into the cell? Bacteria may use nucleosides for something other than nucleic acid synthesis. Once inside the cell the nucleosides undergo either hydrolytic or phosphorylative cleavage separating the sugar (ribose) from the base (Hammer-Jespersen,
1983). The sugar is catabolized and the bases are either catabolized or reincorporated into nucleic acids (Stewart and Carlson, 1986). Bacteria use the products as sources of nitrogen and carbon. Purines, pyrimidines, ATP (adenosine triphosphate), NAD+ (nicotinamide adenine dinucleotide) and FAD (flavin adenine dinucleotide) are examples (Madigan et al., 1997). The phosphate molecules left behind in the soil, after the nucleosides are transported across bacterial cell membranes, may enter the soil phosphorus cycle. Figure 2 is a schematic representation of the RNA cycle in soil and its role as a nutrient source.

RNA nucleosides, not taken up by bacterial cells, and RNA phosphate molecules can enter the carbon, nitrogen, and phosphorus cycles. Microbes are the primary organisms in these cycles and therefore they derive energy and/or cellular compounds indirectly from the RNAs.

It is possible that other microbes also utilize RNA as a nutrient source. Protozoa, amoebae in particular, are abundant in soils and actively seek bacteria, other protists and detritus as food sources.

**SUMMARY**

Nucleic acids have long been looked upon as sources of nitrogen, phosphorus and carbon in the soil. They play a part in nutrient cycling (Lorenz and Wackernagel, 1994). The two major factors limiting microbial activity in soil are water and nutrients. In some soils, inorganic nutrients such as phosphorus and nitrogen are the limiting nutrients (Madigan et al., 1997).

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**REFERENCES**


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**Figure 2. RNA cycle in soil.**


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