COLD TOLERANT MICROBES IN SPOILAGE AND THE ENVIRONMENT

edited by
A. D. Russell & R. Fuller

THE SOCIETY FOR APPLIED BACTERIOLOGY TECHNICAL SERIES NO. 13

COLD TOLERANT MICROBES IN SPOILAGE AND THE ENVIRONMENT

Edited by Additional Bullion

A. D. RUSSELL

Welsh School of Pharmacy, University of Wales Institute of Science and Technology, Cardiff, UK

AND

R. FULLER

National Institute for Research in Dairying, Shinfield, Reading, UK

1979



ACADEMIC PRESS
LONDON · NEW YORK · SAN FRANCISCO
A Subsidiary of Harcourt Brace Jovanovich, Publishers

ACADEMIC PRESS INC. (LONDON) LTD 24/28 OVAL ROAD LONDON NW1

U.S. Edition Published by ACADEMIC PRESS INC. 111 FIFTH AVENUE NEW YORK, NEW YORK 10003

Copyright © 1979 By The Society For Applied Bacteriology

ALL RIGHTS RESERVED

NO PART OF THIS BOOK MAY BE REPRODUCED IN ANY FORM
BY PHOTOSTAT, MICROFILM, OR ANY OTHER MEANS, WITHOUT
WRITTEN PERMISSION FROM THE PUBLISHERS

British Library Cataloguing in Publication Data

Society for Applied Bacteriology. Autumn

Demonstration Meeting, Brunel University, 1977

Cold tolerant microbes in spoilage and the
environment.—(Society for Applied Bacteriology.
Technical series; no. 13).

- Food—Microbiology—Congresses
- 2. Food contamination-Congresses
- 3. Psychotropic organisms—Congresses
- 4. Microbial ecology-Congresses
- I. Title II. Russell, A D III. Fuller, Roy, b. 1933 IV. Series

576'.163 QR115 79–50315

ISBN 0-12-603750-7

Printed in Great Britain by
Latimer Trend & Company Ltd, Plymouth

Contributors

- B. W. Adams, A.R.C. Food Research Institute, Colney Lane, Norwich NR4 7UA, UK
- J. H. Baker, River Laboratory, Freshwater Biological Association, East Stoke, Wareham, Dorset BH20 6BB, UK
- ELLA M. BARNES, A.R.C. Food Research Institute, Colney Lane, Norwich NR4 7UA, UK
- M. Bhakoo, Department of Biological Sciences, The University, Dundee DD1 4HN, UK
- CHRISTINA M. COUSINS, National Institute for Research in Dairying, University of Reading, Shinfield, Reading RG2 9AT, UK
- R. H. DAINTY, A.R.C. Meat Research Institute, Langford, Bristol BS18 7DY, UK
- F. L. DAVIS, National Institute for Research in Dairying, University of Reading, Shinfield, Reading RG2 9AT, UK
- CHARMAIGNE D. HARDING, A.R.C. Meat Research Institute, Langford, Bristol BS18 7DY, UK
- R. A. Herbert, Department of Biological Sciences, The University, Dundee DD1 4HN, UK
- C. S. IMPEY, A.R.C. Food Research Institute, Colney Lane, Norwich NR4 7UA, UK
- B. A. LAW, National Institute for Research in Dairying, University of Reading, Shinfield, Reading RG2 9AT, UK
- J. V. Lee, Public Health Laboratory, Preston Hall Hospital, Maidstone, Kent ME20 7NH, UK
- J. W. LEFTLEY, Dunstaffnage Marine Research Laboratory, P.O. Box 3, Oban, Argyll PA 34 4AD, UK
- VALERIE M. MARSHALL, National Institute for Research in Dairying, University of Reading, Shinfield, Reading RG2 9AT, UK
- G. C. Mead, A.R.C. Food Research Institute, Colney Lane, Norwich NR4 7UA, UK
- SILVIA MICHANIE,* A.R.C. Meat Research Institute, Langford, Bristol BS18 7DY, UK

^{*}Present address: S. A. Frigorifico Monte Grande, San Martin 432/525, Monte Grande, Buenos Aires, Argentina

- M. J. M. MICHELS, Department of Microbiology, Unilever Research Duiven, Zevenaar, The Netherlands
- G. J. Morris, Institute of Terrestrial Ecology, Culture Centre of Algae and Protozoa, 36 Storey's Way, Cambridge CB3 ODT, UK
- C. K. Murray, Torry Research Station, 135 Abbey Road, Aberdeen AB9 8DG, UK
- D. R. Orr, River Laboratory, Freshwater Biological Association, East Stoke, Wareham, Dorset BH20 BB6, UK
- B. Reiter, National Institute for Research in Dairying, University of Reading, Shinfield, Reading RG2 9AT, UK
- M. ELISABETH SHARPE, National Institute for Research in Dairying, University of Reading, Shinfield, Reading RG2 9AT, UK
- B. G. Shaw, A.R.C. Meat Research Institute, Langford, Bristol BS18 7DY, UK
- J. M. Shewan, Torry Research Station, 135 Abbey Road, Aberdeen AB9 8DG, UK
- I. VANCE,* Dunstaffnage Marine Research Laboratory, P.O. Box 3, Oban, Argyll PA34 4AD, UK
- D. D. WYNN-WILLIAMS, Life Sciences Division, Bristol Antarctic Survey, Madingley Road, Cambridge CB3 OET, UK

^{*}Present address: Department of Life Sciences, Polytechnic of Central London, London W1M 8JS, UK

Preface

This volume, Number 13 in the Society for Applied Bacteriology Technical Series, is based on the demonstrations made at the Autumn 1977 Demonstration Meeting of the Society.

The subject of the meeting was "Cold Tolerant Microbes in Spoilage and the Environment". The book brings together contributions from experts on psychrotrophic bacteria and contains chapters on various aspects of low temperature microbiology as they affect fundamental metabolism, ecology and food spoilage. Providing as it does an excellent survey of the importance of psychrotrophic bacteria it will be of value generally to bacteriologists and is essential reading for those engaged in this particular field.

We would like to thank those who presented demonstrations at this meeting, members of the staff of the Department of Biology, Brunel University, especially Professor J. D. Gillett, Mr. F. Jones (Senior Lecturer) and Mrs. S. Bannerman (Chief Technician) who helped in the staging of this demonstration, and Mr. D. W. Lovelock of Heinz Co. Ltd., for his help and advice.

February 1979

A. D. RUSSELL R. FULLER

Contents

Lis	r of Contr	IBUTO	RS							14	v
								•	•		vii
LILL	I ACL	7.0	1.1	5 10		•					* * * *
Mic	robial Grov	wth at	Low	Tem	nerat	ures					1
	. A. HERBER				-						
	Introduction							,			1
	Distribution									•	
	Taxonomy										2 2 3
	Growth of 1										3
	Temperatur			.5							5
	Significance			hilon					- mta	1	13
					111 145	iturai	LIIVII	OHHIE	ints		14
	Acknowledg	,		*							14
	References	× 5					•	•			14
			.17	don't	prilime.	X 11	100			JI .	
	Response		cellu	lar Al	lgae to	o Free	ezing	and	Thaw	ing	17
G	. J. Morris										
	Introduction	a.									17
	Viability As	says	X 10 1								17
	General Me	thods	used	in Fr	eezing	and T	Γhawi	ng			18
	References										22
The	Constructi	on an	d Apı	olicat	ion o	Tem	pera	ture	Gradi	ent	
(5)a	Incubators				22121 -						25
T	H. BAKER A		R C)RR							
٠,٠	Introduction										25
	Theory and				f Ten	nnerat	ure (Fradie	nt Ir	CII-	
	bators	Con	struct	1011 0		·	uic (JIAGI			26
	Commercial	1 . A	·ilable	Tom	· noroti	ra C	endian	t Inc	, hator	*0	35
	Application	ny Ava	mable	1 CII.	Crad	iont T	auten	t 1110	uDatoi		36
	A A		-	ature	Grad	ient ii	ncuba	tors			37
11	Acknowledg	gement		*		*	•				
	References					*		*			37
					1X						

X CONTENTS

Determination of Heat R								
formers by means	of t	he "	Screw	-cap	Tube	e" Te	ch-	
nique		*						39
M. J. M. MICHELS								
Introduction						*		39
Production of Spore Su					istanc	e Stu	dies	40
The Original Screw-cap								42
Modifications to the Sc	rew-c	ар Ті	ibe Te	chnic	lue			43
Temperature Profile for	Inje	cted S	pores					44
Enumeration of Spores						ues		47
Discussion							150	48
Acknowledgements			*		*		98	49
References	· June					•		49
An Inflatable Anaerobic C	Glove	Bag						51
J. W. LEFTLEY AND I. V.								
Introduction								51
Specifications								52
Operation	1,0							54
Applications	100		F."	5				55
Acknowledgements					*			56
References			x.I					57
Alteromonas (Pseudomon	are)	hartma	Facian					59
J. V. LEE	ius j į	Juirej	ucien	٥				3)
Introduction								59
Sources and Significance								59
Description and Charac		ce of	A but	vofaci	one	•		60
Isolation and Identificat		105 01	_					61
Taxonomic Consideration				*		•		62
References			•		*	•	*	64
References					•	•	•	01
Techniques Used for Stud				1 Mic	crobia	al		
Ecology in the Mariti	me A	ntar	etic	W.		*		67
D. D. WYNN-WILLIAMS								
Introduction						• 7		67
Selection of Sampling A	reas				*	×	*	67
								68
Treatment of Samples							Α.	70
Culture Media and Stair	ning l	Proce	dure					73
								75
Gilson Respirometry	× .							75

	CONTENTS	κi
	Farmers Farmers	6
	Environmental Measurements	7
	Results	9
	Acknowledgements	9
	References	0
	The Spoilage of Vacuum-packed Beef by Cold Tolerant	
		3
	R. H. DAINTY, B. G. SHAW, CHARMAIGNE D. HARDING AND	
	SILVIA MICHANIE	
1	Introduction	3
		5
		0
	Acknowledgements	7
	References	8
	Spoilage Organisms of Refrigerated Poultry Meat 10	1
	ELLA M. BARNES, G. C. MEAD, C. S. IMPEY AND B. W. ADAMS	
	Introduction	1
	Methods	1
	Control in the Processing Plant	5
	Processed Carcass	
	Summary	
	References	4
	The Microbiol Spoilage of Fish with Special Reference to	
	the Role of Psychrophiles	7
	J. M. SHEWAN AND C. K. MURRAY	
	Introduction	7
	Introduction	7
	Definition of Psychrophile	8
	Microbial Invasion of Fish Tissues and Associated Sensory	
	Changes during Spoilage	8
	Changes in the Microbial Flora during Spoilage 12	
	Differing Rates of Spoilage of Various Fish Species 12	
	Possible Reasons for Differing Spoilage Rates	-
	References	
	Psychrotrophs and their Effects on Milk and Dairy Products 13	7
	B. A. Law, Christina M. Cousins, M. Elisabeth Sharpe	ъ.
	AND F. L. DAVIES	
	Introduction 13	7

CONTENTS

	Methods					*					137
	Enumeration	and	Grow	th of	Psych	rotro	phic Ba	cteria	in R	aw	
	Milk .		-								139
	Lipolytic an	d Prot	eolyti	c Psyc	chrotr	ophs	in Raw	Milk			143
	Psychrotrop	hic Sp	orefo	rming	Bacte	eria					148
	Acknowledg	ement	S			0.01					150
	References	* 1		ů.		•	1.	*.		*	150
Bac	tericidal Ac	tivity	of th	e Lac	toper	oxid	ase Sys	stem	agai	nst	
	Psychrotro	phic F	seud	omor	ias si	p. in	Raw	milk			153
В	. REITER ANI										
	Introduction	١.					×				153
	The Lactope	eroxida	ase Sy	ystem			116				154
	The Bacteri	cidal A	Activi	ty of	the L	P Sys	stem ag	gainst	Pseu	do-	
	monas spp	. in a	Synth	netic N	I ediu	m					154
	The Nature	of the	Bact	ericida	al Act	ivity	of the I	LP Sy	stem	IR.	156
	The Prevent	ion by	the I	P Sys	tem o	f Spo	ilage of	Chee	ese ma	ıde	
	from Milk	conta	mina	ted wi	th Ps	. fluor	rescens			12	159
	Conclusions								Χ.		163
	Acknowledge	ement	S			14 (F)					163
	References				•						163
Sub	JECT INDEX										165

Microbial Growth at Low Temperatures

R. A. HERBERT AND M. BHAKOO

Department of Biological Sciences, The University,
Dundee, Scotland

and of Journey of June 18 and the Introduction used odd or archive a dately

Temperature is undoubtedly one of the most important environmental parameters operating in any ecosystem. The fundamental role of temperature in controlling the rate of all physico-chemical reactions underlies its significance when considering the complexities of biological processes. Micro-organisms, since they can be cultivated with relative ease in the laboratory, provide a convenient experimental tool for elucidating the effects of temperature on living cells. Most micro-organisms can grow only over a relatively narrow temperature range, from about $-10^{\circ}\mathrm{C}$ to $+70^{\circ}\mathrm{C}$, and within this range, temperature affects the growth rate, nutritional requirements, enzyme activities and chemical composition of the cells. Considering the profound effects of temperature, it is somewhat disturbing that many microbiologists conveniently neglect the fact that most natural environments are at low temperatures. The literature is, however, replete with examples of micro-organisms whose physiology was studied at temperatures in excess of those from which they were obtained.

Traditionally, micro-organisms have been classified on the basis of temperature optima for growth into thermophiles, mesophiles and psychrophiles according to their ability to grow at high, medium and low temperatures, respectively. The first two groups can be readily differentiated by their growth temperature optima. Psychrophiles have also been defined following their discovery by Forster (1887) but it is only during the last decade that some semblance of agreement has been achieved amongst microbiologists in defining these organisms. For detailed discussions on the definition of psychrophiles the reader should consult reviews by Ingraham and Stokes (1959) and Morita (1966, 1975). For the purpose of this review the definition of psychrophiles as proposed by Morita (1975) will be used, i.e. organisms having an optimal growth temperature of about 15°C or lower, a maximal growth temperature of

此为试读,需要完整PDF请访问: www.ertongbook.com

about 20°C and a minimal growth temperature of 0°C or lower. Bacteria which grow at 0°C and at maximum temperatures exceeding 25°C will be considered to be psychrotrophic.

Distribution of Psychrophilic Bacteria

The ability of micro-organisms, and in particular bacteria, to grow at low temperatures was first demonstrated by Forster (1887) and subsequently they have been shown to have a widespread distribution in a range of natural environments (Ingraham and Stokes, 1959; Morita. 1966). The majority of the isolates obtained by the early investigators were psychrotrophic and the occurrence of truly psychrophilic bacteria, which conform to the present definition, were not reported until 1964. Morita and Haight (1964) isolated the first authentic psychrophilic bacterium, Vibrio marinus MP-1, and subsequently they have been isolated from a range of habitats (Harder and Veldkamp 1967; Stanley and Rose, 1967; Moiroud and Gounod, 1969; Herbert and Bell, 1977). The principal reason for the inability of early microbiologists to isolate psychrophiles was the failure to use pre-cooled media and to ensure that the samples were never exposed to lethal temperatures. These organisms are abnormally thermolabile and even exposure to room temperature for a period of time is likely to be lethal. However, if pre-cooled media are used, psychrophiles can be obtained relatively easily from permanently cold environments. The majority of psychrophiles studied have been isolated from the marine environment but they are not confined to this

Taxonomy of Psychrophilic Bacteria

A notable feature of psychrophilic bacteria is the predominance of Gram negative species isolated and the relative rarity of Gram positive organisms. Most of the psychrophiles studied belong to the genera Vibrio and Pseudomonas (Morita and Haight, 1964; Harder and Veldkamp, 1967; Herbert and Bell, 1977). Chromogenic isolates have been assigned to the genus Flavobacterium (Stanley and Rose, 1967; Sieburth, 1967), although the taxonomic status of the genus is at present uncertain. Gram positive psychrophiles have been isolated. Sieburth (1967) isolated Arthrobacter spp. from Narragansett Bay, Rhode Island and a similar organism, A. glacialis, has been isolated from sediments below arctic glaciers (Moiroud and Gounod, 1969). Until recently there had been no reports of psychrophilic anaerobes. Sinclair and Stokes (1963) successfully isolated from soil, mud and sewage Clostridium spp. which were

capable of sporulating at 0°C, but these were shown to be psychrotrophs. Liston *et al.* (1969) and then Finnes and Matches (1974) were the first to report psychrophilic *Clostridia* in marine sediments from Puget Sound. Sixteen of these isolates had growth temperature maxima below 15°C.

Herbert and Bell (1973, 1974) made an extensive survey of the waters and sediments of the lakes and offshore coastal waters for psychrophilic

TABLE 1. Bacterial groups isolated from freshwater lakes and coastal offshore waters at Signy Island, South Orkney Islands,
Antarctica

Bacterial group	Marine	Freshwater	
Azotobacter sp.	+	+	
Nitrosomonas sp.	-	+	
Nitrobacter sp.		+	
Dentrifier sp.	+	+	
Proteolytic sp.	+	+	
Purple non-sulphur sp.	+	+	
Purple sulphurs	+	+	
Green sulphurs	+	+ .	
Thiobacillus sp.	+	+	
Filamentous S-oxidizers			
(Beggiatoa)	ND	+	
Sulphate reducers	+	+	
Sulphur oxidizers	+	ND	
Cellulose decomposers	4	+	

ND, not determined.

representatives of other bacterial groups. Table 1 shows the diversity of bacterial types that were isolated. The majority of the isolates obtained were psychrotrophic. Although psychrophilic representatives of some groups have been obtained they are present in relatively small numbers. It seems paradoxical that in such permanently cold-environments (lake temperature maximum 5° C, sea temperature maxima -1° C) that a greater proportion of the microflora is not psychrophilic.

Growth of Psychrophiles

The growth characteristics of psychrophilic bacteria have been studied extensively over the last decade. Unfortunately, many of these studies have been performed on batch grown cultures which make interpretation of the data difficult. Our data, like those of Harder and Veldkamp (1967), relate to psychrophilic bacteria grown in a chemostat. In this way, by growing the cells at a constant growth rate, the effect of temperature can be studied as a single environmental factor without the complication of

appoint of a relating at TC, but there were shown in he prochessingle, but at all 1999 and once France and Victors [1975] were the first to report payed rophilis Convention may be ashimony from Prace countd

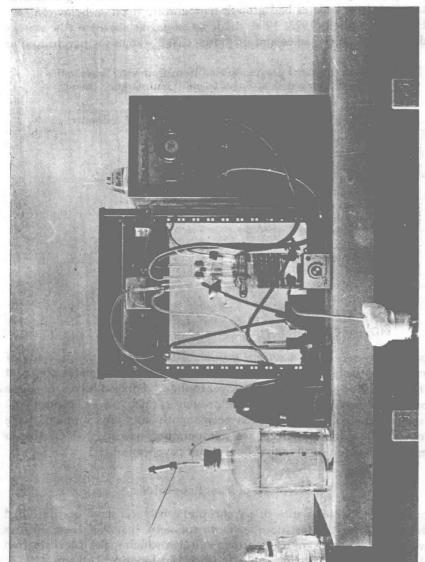


Fig. 1, Chemostat arrangement for growing psychrophilic bacteria

relation to psychrophilic bacteria grown in a chemostri. In this way, he growning the cells at a constant erous of the class of temperature and new coding as a single environmental forth with at the complication of

changes in growth rate, nutrient concentration, pH, dissolved gas concentrations which occur during the growth of bacteria in batch culture. In our own work we have used a simple single stage 1 litre chemostat (Fig. 1) based on the design of Baker (1968). Cooling is provided from an external thermocirculator (Churchill Instruments Ltd) circulating coolant via a "cold-finger" or cooling coil in the chemostat. In order to standardize the growth conditions we have used a defined mineral salts medium (Brown and Stanley, 1972) supplemented with glucose as carbon source and either KNO₃ or NH₄Cl as nitrogen source.

Temperature Effects

Effect of temperature on growth rate

It is a widely held belief that psychrophilic bacteria grow slowly at near zero temperatures. A closer examination of the literature shows that this is not necessarily the case. Vibrio marinus MP-1, for example, has a mean generation time of 226 min at 3°C (Morita and Albright, 1965) whilst Larkin and Stokes (1969) claim that Bacillus cryophilus will double its population every 6 h at -5°C. Other psychrophilic bacteria are much slower growing. Micrococcus cryophilus has a doubling time of 28·33 h at 0°C and Vibrio AF-1 (Herbert and Bell, 1977) has a mean generation time of 23 h. It may well be that it is not the rate of growth which is important but the efficient conversion of substrate carbon into cell carbon which is significant.

Following the derivation by Arrhenius (1889) of an equation to describe the effects of temperature on chemical reactions,

$$K = Ae^{-E|RT|}$$
where the political property and because 1 and 2.

where K is the reaction rate, R the gas constant, T the absolute temperature, $E(\mu)$ the activation energy and A a constant, many microbiologists have attempted to apply the equation to the growth of bacterial cultures. By substituting bacterial growth rate for K in the equation the temperature characteristic for growth (μ) can be determined. Ingraham (1958, 1962) originally proposed that this could be used to determine whether or not a particular micro-organism was a psychrophile or a mesophile since the former should have a lower μ value. Ingraham's data have been challenged by Janota-Bassalik (1963) and Hanus and Morita (1968) on the grounds that his calculations were erroneous. The latter authors could find no significant difference between the μ values of a psychrophile, a psychrotroph and a mesophile. Similar findings have been reported for

Table 2. Optimal growth temperatures and temperature characteristic of growth (μ) for 5 psychrophilic *Vibrio* spp.

Isolate number	Optimal growth temperature (0°C)	Temperature characteristic for growth
AM1	I strumpe of L. Series	27 400
AM10	10	32 000
AF1	15	9900
BM2	4	8200
BM4	8	38 700

yeasts (Shaw, 1967) and Gram positive bacteria (Brownlie, 1966). We determined μ values for 5 psychrophilic *Vibrio* spp. (Table 2) and these similarly show no consistent values. Whilst μ values may be of doubtful validity in describing the growth characteristics of psychrophiles and mesophiles, the Arrhenius plot of log specific growth rate against 1 / $^{\circ}$ K is significant. In the case of psychrophiles, the slope of the Arrhenius plot is linear down to 0°C and below, whilst psychrotrophs deviate from linearity about 4–5°C and mesophiles tend to deviate from a straight line at higher temperatures (Harder and Veldkamp, 1971).

Effect of temperature upon substrate uptake

The theory that permeability and the associated control of solute transport may constitute a major factor in the ability of psychrophilic microorganisms to grow at low temperatures has gained considerable support and evidence in recent years. The minimum temperature for the growth of mesophiles is considered by many authors to be controlled by the low temperature inhibition of substrate uptake (Ingraham and Bailey, 1959; Rose and Evison, 1965; Morita and Buck, 1974). Even in a psychrotrophic Vibrio, Paul and Morita (1971) found that uptake of 14C-glutamate was much reduced at low temperatures. However, Baxter and Gibbons (1962) and Cirillo et al. (1963) showed that in a psychrophilic Candida sp. sugar transport was largely independent of temperature. These data have been subsequently confirmed for Gram positive and negative bacteria (Wilkins, 1973). In M. cryophilus uptake of lysine occurred at the same rate when the cells were grown at 0°C as at 20°C (Russell, 1971). Herbert and Bell (1977) showed that in Vibrio AF-1 maximum uptake of 14Cglucose and lactose occurred at 0°C and decreased with increasing temperature. Using statistical analysis (analysis of variance) these authors found that the temperature of assay and not the temperature at which the cells were grown was the factor controlling the rate of sugar uptake, i.e. there appear to be no quantitative differences in the number of glucose or

lactose permease molecules present in the cells when grown at different

temperatures. The leaves to methodolog block

Closely allied to the effects of temperature on substrate uptake are the effects on the composition of the membrane lipids. Micro-organisms, in common with most other poikilothermic and many homeothermic organisms, synthesize increased proportions of unsaturated fatty acids, at the expense of saturated acids, when the growth temperature is lowered (Farrell and Rose, 1967). It is well known that an increase in the degree of unsaturation in lipids causes a decrease in the melting point of the lipids. A number of workers have argued that the physiological effect of the increased synthesis of unsaturated fatty acids at low temperatures is to maintain the membrane lipids in a fluid, and therefore mobile, state. This "lipid solidification" theory has been difficult to demonstrate experimentally. Circumstantial evidence for the theory has been provided by studies on cold shock in mesophilic and psychrophilic pseudomonads (Farrell and Rose, 1968). Pseudomonas aeruginosa, a mesophile, when grown at 30°C is susceptible to cold shock and loses viability whereas when grown at 10°C the cells are no longer susceptible. At the lower temperature (10°C) increased levels of unsaturated fatty acids are synthesized and Farrell and Rose (1968) postulate that these prevent lesions forming in the cytoplasmic membrane, thus maintaining their integrity. Additional evidence to support this hypothesis was the demonstration that a psychrotrophic pseudomonad which had increased unsaturated fatty acid levels at 30°C, was less susceptible to cold shock than the mesophile at this temperature. These data provide evidence that solute transport may well be influenced by the degree of unsaturation of the fatty acid side chains of the membrane lipids.

Several studies have been made of the changes in fatty acid composition of membrane lipids with temperature; however, the interpretation of certain of these data is difficult since the organisms were grown in batch culture and it is known that fatty acid composition alters in respect of growth rate as well as temperature. Comparative studies of mesophilic and psychrophilic yeasts have shown that the psychrophiles are generally endowed with a higher proportion of unsaturated fatty acids than the mesophiles (Kates and Baxter, 1962; Brown and Rose, 1969a). Data on psychrophilic bacteria have not provided such clear-cut findings. Kates and Hagen (1964) examined mesophilic and psychrophilic Serratia spp. and concluded that the psychrophilic species produced increased unsaturated fatty acids (hexadecenoic and octadecenoic acids) compared with the mesophiles. In M. cryophilus the response to low temperature is somewhat different and involves a shortening of the fatty acid chain length rather than increased synthesis of unsaturated fatty acids (Russell,