

Trace Element Metabolism in Man and Animals

Edited by

J. M. Gawthorne, J. McC. Howell, C. L. White

Trace Element Metabolism in Man and Animals

Proceedings of the Fourth International Symposium on Trace
Element Metabolism in Man and Animals (TEMA-4), held in
Perth, Western Australia 11–15 May 1981

Edited by

J. M. GAWTHORNE
J. McC. HOWELL
C. L. WHITE

SPRINGER-VERLAG
BERLIN HEIDELBERG NEW YORK 1982

Dr. J. M. Gawthorne
Division of Veterinary Biology
School of Veterinary Studies
Murdoch University
AUS-Murdoch, WA 6150

Prof. J. McC. Howell
Division of Veterinary Biology
School of Veterinary Studies
Murdoch University
AUS-Murdoch, WA 6150

Dr. C. L. White
CSIRO Division of Animal Production
AUS-Wembley, WA 6014

Publisher outside Australia:
Springer-Verlag Berlin Heidelberg New York

Publisher in Australia:
Australian Academy of Science
PO Box 783, Canberra City, 2601

ISBN 3 540 11058 5 Springer-Verlag Berlin Heidelberg New York
ISBN 0 387 11058 5 Springer-Verlag New York Heidelberg Berlin

ISBN 0 85847 099 3 Australian Academy of Science

This work is copyright. All rights reserved. Permission
must be obtained in writing from the Australian Academy of Science if
reproduction is required.

© Copyright Australian Academy of Science 1981

Printed in Australia

Printing and bookbinding: Griffin Press Limited, Netley, South Australia

2131/3140-543210

PREFACE

The Fourth International Symposium on Trace Element Metabolism in Man and Animals (TEMA-4), was held in the Sheraton Hotel, Perth, Western Australia from May 11 to 15, 1981. One of the aims of TEMA-1, which was held in Aberdeen in 1969, had been to promote a meeting at which involved scientists from a variety of disciplines would be given the opportunity to present and discuss recent research findings. It was our intention to maintain this aim. We also intended to continue the initiative taken at TEMA-3, held in Freising-Weihenstephan in 1977, which was to encourage participation by our colleagues in human medicine. We feel that a pleasing degree of success was achieved for both these aims.

The decision to hold TEMA-4 in Perth was made at the TEMA-3 meeting in 1977. The International Guiding Committee wished to acknowledge the significant body of work on trace element metabolism and disorders that had been undertaken in Australia. But in particular they wished to pay tribute to Professor Eric Underwood who for so long had been guide and mentor to so many scientists working on problems associated with trace elements. Eric was the obvious choice as Chairman of the Local Organising Committee and he set about his task with his usual vigour and good humour. We were all shocked and saddened by his death in August 1980. We feel sure that the decision to continue with arrangements for the TEMA-4 meeting is what he would have wished us to do. The members of the Local Organising Committee hope that in some measure the meeting and the Proceedings of the Fourth International Symposium on Trace Element Metabolism in Man and Animals will serve as a memorial to the work of this unique and most gifted man of science.

The Symposium was attended by 210 scientists from 24 countries, which was a most gratifying response in view of the ever increasing cost of travel. We chose six speakers for our plenary sessions and invited active workers in the field of trace element studies to submit abstracts. One hundred and forty seven contributions were presented verbally and a further twenty three were presented as posters. A wide variety of topics were covered and we were particularly pleased to have presentations and active discussions in such areas as the effect of trace elements on the development of the central nervous system and the role of trace elements in human disease. Many new ideas were presented and considerable interest centred around the series of papers given on aspects of zinc metabolism and on the role of metallothioneins.

To assist the rapid publication and to minimise the cost of the Proceedings we chose to use an offset litho process and a 'camera ready' system was used for manuscript preparation. The importance of the discussion of the contributions was recognised. We chose to record the discussions which were then typed so that they were available for correction during the meeting. In order to minimise the delay between the meeting and the publication of the Proceedings the manuscripts and discussions were lightly edited and a minimum number of changes were made. This has involved some retyping and the editors accept responsibility for the changes that may have occurred at this stage.

We wish to thank all participants and session chairpersons for their valuable contributions to the meeting. We are grateful to the Secretariat who have worked with such dedication on the manuscripts and discussion of the papers. We acknowledge the financial support of our sponsors, without their aid the Symposium could not have taken place. We are grateful to the members of the International Guiding Committee and the Local Organising Committee who worked hard and long for the success of the meeting.

J. McC. Howell

J. M. Gawthorne

C. L. White

Perth 1981

CONTENTS

Introductory Lecture

Eric John Underwood, FRS; A Colleague, Mentor and Friend C.F. MILLS	3
------------------------------------------------------------------------------	---

Trace Element Status and Requirements

Trace Element Needs of Species in Relation to Body Size R.M. SMITH	9
The Dietary Intake of Trace Elements in Sweden M. ABDULLA, S. SVENSSON, A. NORDÉN and P-A. ÖCKERMAN	14
Copper and Zinc Status of Parenteral Nutrition Patients T.F. HARTLEY, L.G. WORTHLEY, B. DOLLMAN and P. COYLE	18
Glutathione Peroxidase and Selenium Status C.D. THOMSON and A. DUNCAN	22
Selenium in Platelets of Children with Low Selenium State I. LOMBECK, K. KASPEREK, G.V. IYENGAR, J. KIEM, L.E. FEINENDEGEN and H.J. BREMER ..	26
Selenium Status of Seven IVH Patients H.W. LANE, A.O. BARROSO, S.J. DUDRICK, D.A. ENGLERT and B.V. MacFADYEN	30
Soil Type and Cattle Blood Selenium Levels in the North Island of New Zealand A.J. FRASER and J.A. KIRK	34
Some Aspects of a Survey into Selenium Deficiency in Cattle in Northern California J.D. WILLIAMS, W.H. JOHNSON, B.B. NORMAN, H.F. MAYLAND and J.R. DUNBAR	39
Effects of Hormonal Changes on the Selenium and Glutathione Peroxidase Levels in the Rat D. BEHNE, T. HÖFER, W. WOLTERS, R. von BERSWORDT-WALLRABE, W. ELGER, P. BRÄTTER and D. GAWLIK	43
The Selenium Status of Horses in Western Australia N.D. COSTA, H.G. MASTERS, P. STEELE, B.J. HILBERT, J.F. HUDMAN and J.R. BOLTON	44
Cu, Mo, S, Zn Periodontitis in Brazilian Cattle W.V. de A. CAMARGO, J.S. VEIGA and J.H. CONRAD	47
Mineral Status of Cattle in Tropical Lowlands of Bolivia B. BAUER, E. GALDO, L.R. McDOWELL, M. KOGER, J.K. LOOSLI and J.H. CONRAD	50
Mineral Status of Grazing Farm Animals in Malaysia R.I. HUTAGALUNG, P.Y. HEW, M.R. JAINUDEEN, T.A. BONGSO and S. JALALUDIN	54
Defining a Diagnostic Plasma Vitamin B ₁₂ Concentration for Cattle A. MacPHERSON	58
Iodine Status and Thyroid Activity of White-Tailed Deer B.E. WATKINS, D.E. ULLREY, S.M. SCHMITT and R.F. NACHREINER	61

Copper Status of Cattle in the South East of South Australia J.D. McFARLANE and G.J. JUDSON	63
<u>Trace Element Balance Studies and Homeostasis</u>	
Method of Trace Metal Balance in Children M.H.N. GOLDEN, B.E. GOLDEN and A.A. JACKSON	69
Dietary Zinc and the Output and Composition of Faeces B.E. GOLDEN and M.H.N. GOLDEN	73
Interpretation of Trace Element Balance in Adult TPN G.D. PHILLIPS and V.P. GARNYS	77
The Intake and Urinary Excretion of Electrolytes and Trace Elements M. ABDULLA, A. NORDÉN, B. SCHERSTÉN, S. SVENSSON, T. THULIN and P-A. ÖCKERMAN	81
Changes in the Metabolism (Retention, Absorption, Excretion) of Copper, Zinc, and Manganese in Gravidity and Lactation M. KIRCHGESSNER, F.J. SCHWARZ and D.A. ROTH-MAIER	85
The Roles of the Liver and Gut in Mn Homeostasis in Cattle E.D. HALL, H.W. SYMONDS and W.M. ALLEN	89
The Quantities of Zn, Cu, Mn and Fe Secreted in the Parotid and Mandibular Salivas of Sheep Fed Lucerne Chaff or Perennial Ryegrass N.D. GRACE, D.H. CARR and C.S.W. REID	92
Zinc Metabolism in Sheep given a Hay Diet H. LLOYD DAVIES, N.F. SUTTLE and A.C. FIELD	96
Effect of Dietary Tin on Human Mineral Utilization J.L. GREGER, M.A. JOHNSON and M.J. BAIER	101
<u>The Availability, Absorption and Retention of Trace Elements</u>	
Improvement of Zinc Bioavailability in Cereal Grains H. -J. LANTZSCH, S.E. SCHEUERMANN and H. MARSCHNER	107
Influence of Dietary Protein on Zinc Availability from Bread in Rats J.M. MCKENZIE and N.T. DAVIES	111
Effect of Dehulling on Zinc Availability of Field Beans H.-J. LANTZSCH and S.E. SCHEUERMANN	114
A Vascular Perfusion Technique for the Study of Zinc Absorption L. STEEL, D. McMASTER and A.H.G. LOVE	117
Zinc Absorption by Vascularly Perfused Small Intestine D. McMASTER, L. STEEL and A.H.G. LOVE	121
Absorption of Zinc and Manganese in Relation to Age M. KIRCHGESSNER, E. WEIGAND and F.J. SCHWARZ	125
<u>In Vitro</u> Interaction of Phytate with Trace Elements D. OBERLEAS and N. MOODY	129
Tissue Copper Retention or Loss in Young Growing Cattle A.M. SIMPSON, C.F. MILLS and I. McDONALD	133
Genetic and Dietary Factors in Cu Accumulation by Sheep J.A. WOOLLIAMS, N.F. SUTTLE, G. WIENER and A.C. FIELD	137
Copper Dependent Enzymes in Mottled Mouse Mutants M. PHILLIPS, J. CAMAKARIS, J. MANN and D.M. DANKS	141

Mechanism and Regulation of Intestinal Copper Absorption T. SONSMA, P. HIXON, K. McWILLIAMS and M.C. LINDER	145
Complex Speciation for Absorption and Excretion P.M. MAY and D.R. WILLIAMS	149
Metal Binding by Infused Chelates J.R. DUFFIELD, P.M. MAY and D.R. WILLIAMS	152
Low Molecular Weight Metal Compounds in Edible Plants C.D. WALKER and R.M. WELCH	155
Modified Food Starch Ingestion in Hamsters and Rats : Effects of Magnesium and Calcium M.L. BUTTOLPH and P.M. NEWBERNE	158
Metabolic Patterns of Arsenic as Studied by Neutron Activation Analysis and Radiotracer Methods E. MARAFANTE, J. EDEL-RADE, R. PIETRA, E. SABBIONI and F. BERTOLERO	162
Biopotency of Selenium for Glutathione Peroxidase Synthesis R.A. SUNDE, W.K. SONNENBURG, G.E. GUTZKE and W.G. HOEKSTRA	165
Dietary Selenium and Rat Platelet Glutathione Peroxidase O.A. LEVANDER and V.C. MORRIS	169
<u>Trace Element Supplementation</u>	
Field Studies with Trace Element Metering Devices A. MacPHERSON	175
Effect of Copper Supplementation on Fertility in Heifers B.E. RUKSAN, A. CASARO, J. JAESCHKE, F. LAGOS and D.G. PONDAL	179
Hypocuprosis in Cattle in Central Queensland, Australia G.M. MURPHY, C.K. DIMMOCK, T.P. KENNEDY, M.S. O'BRYAN, A.W. PLASTO, E.E. POWELL J.O. TWIST, G.S. WRIGHT and R.J.W. GARTNER	183
Oxidised Copper Wire for Oral Copper Therapy in Cattle G.J. JUDSON, D.W. DEWEY, J.D. McFARLANE and M.J. RILEY	187
Treatment of Cobalt Deficiency in Calves G.J. JUDSON, J.D. McFARLANE, M.J. RILEY, M.L. MILNE and A.C. HORNE	191
Controlled Release Glasses for Selenium Supplementation W.M. ALLEN, P.R. MOORE and B.F. SANSOM	195
Effect of Zn-Containing Pellets on Selenium Pellet Function D.W. PETER, A.W. MANN and R.A. HUNTER	199
Effect of Selenium and Vitamin E on Calf Weight Gains W.H. JOHNSON, B.B. NORMAN and J.R. DUNBAR	203
Selenium and Vitamin E for Weanling Swine D.C. MAHAN and A.L. MOXON	207
Selenium and Tocopherol Treatment of Ovine Weaner Nutritional Myopathy P. STEELE, D.P. MCKENZIE, S. SKIRROW, R.L. PEET and G. DONCON	210
The Effect of Se Grain-size on the Efficacy of Selenium Pellets D.R. HUDSON, R.A. HUNTER and D.W. PETER	214
Optimum Se Grain size for Selenium Pellets D.W. PETER, R.A. HUNTER and D.R. HUDSON	218

Intensive Grazing Practices and Selenium and Vitamin B ₁₂ Nutrition of Sheep C. HALPIN, I. CAPLE, P. SCHRODER and R. MCKENZIE	222
Effect of Supplemental Selenium on the Performance and ⁷⁵ Se Metabolism in Chicks J.S. EDWARDLY	226
A New Method for Preventing Iron Deficiency Anaemia in Piglets P.T. GLEED, B.F. SANSOM and W.M. ALLEN	230
The Retention and Distribution of ⁵⁹ Fe in Chicks with Fowl Typhoid Given Diets Containing Added Iron in Different Forms R. HILL and I.M. SMITH	234
Zinc, Copper and Magnesium in Serum of Women Given a Calcium Supplement N.E. JOHNSON, J.L. GREGER, K. KUSSEROW, F. SEYEDABI and E.L. SMITH	237
<u>Trace Elements in Pregnancy and Lactation</u>	
Zinc Nutrition and Pregnancy in Humans S. JAMESON	243
Trace Elements in Milk from Various Species B. LÖNNERDAL, C.L. KEEN and L.S. HURLEY	249
Zinc-Binding Ligands in Human Milk S.V. RUMBALL, E.W. AINSCOUGH, A.M. BRODIE, J.E. PLOWMAN, H.M. BAKER and H.J.L. BROOKS	253
The Zinc Status of Breast and Bottle Fed Infants L. MACDONALD, R.S. GIBSON and D. SHAPCOTT	257
Trace Element Content of Breast Milk of Indian Women R. KRISHNAMACHARI	261
Some Aspects of the Effects of Oral Contraceptives on Trace Element Metabolism F.J. CUMMING, M.H. BRIGGS and J.J. FARDY	265
Low Zinc Diet: Effect on Pregnant and Lactating Ewe J. APGAR, W.A. HOUSE and R.M. WELCH	268
<u>Trace Elements and the Development of Organs and Tissues</u>	
Changes in Brain Enzymes Accompanying Deficiencies of the Trace Elements, Copper, Selenium, or Zinc J.R. PROHASKA	275
Trace Elements, Genetic Factors and Drugs in Developmental Abnormalities L.S. HURLEY, C.L. KEEN, B. LÖNNERDAL, P. MARK-SAVAGE and R. HACKMAN	283
Developmental Changes in Zinc and Copper in Mouse and Rat Tissues C.L. KEEN, B. LÖNNERDAL and L.S. HURLEY	287
Prevention of Delayed Swayback in Lambs G. LEWIS, S. TERLECKI, B.N.J. PARKER and P.L. DON	291
Copper and the Pathogenesis of Enzootic Ataxia R.M. SMITH, R.A. KING, W.S. OSBORNE-WHITE and F.J. FRASER	294
Swayback Lesions and Vulnerable Periods of Development J.McC. HOWELL, D.A. PASS and S. TERLECKI	298
Copper Deficiency and Timing of Hypomyelination M. PERLMAN, B. BUCHANAN and B. SARKAR	302

Failure to Confirm Copper Deficiency in Crinkled Mice J.R. MANN, J. CAMAKARIS, J.M. GILLESPIE, B. KOELLREUTER, J.M. MATHIEU, P.M. ROYCE and D.M. DANKS	305
Fetal Iodine Deficiency B.S. HETZEL	309
Reversal of Brain Retardation in Iodine-Deficient Fetal Sheep B.J. POTTER, M.T. MANO, G.B. BELLING, P.F. ROGERS, D.M. MARTIN and B.S. HETZEL	313
<u>Trace Element Deficiencies</u>	
Metabolic Functions of Zinc - A New Look B.L. O'DELL	319
Problems and Possibilities in Diagnosing Zinc Deficiency M. KIRCHGESSNER and H.-P. ROTH	327
Low Zinc and Reproduction in the Ewe D.G. MASTERS	331
Nutritional Zn Deficiency and Metabolism of Insulin and Growth Hormone H.-P. ROTH and M. KIRCHGESSNER	334
Regulation of Protein Intake in Zinc Deficient Rats P.G. REEVES and B.L. O'DELL	338
A Study on Experimental Acrodermatitis Enteropathica S. YAGI and T. MORISHIMA	342
Influence of Zinc on Synthesis and Accumulation of Collagen in Early Granulation Tissue I. TENGRUP, J. AHONEN and B. ZEDERFELDT	348
Selenium Studies - Trepidations, Tissue Calcification and Selenoamino Acids P.D. WHANGER and M.A. BIELSTEIN	348
Selenium and Reproductive Efficiency in Cattle H.R. CONRAD, J.H. HARRISON, T.A. REINHARDT and A.L. MOXON	352
Myopathy in Selenium Deficient Cattle J.R. ARTHUR	356
Effects in Pigs Fed the Crops Grown in Keshan Disease Affected Province of China L.Z. ZHU and Z.H. LU	360
Comparative Effects of Selenium Deficiency on Male Reproduction in Several Mammalian Species F.R. POND, M.J. TRIPP, A.S.H. WU, P.D. WHANGER and J.E. OLDFIELD	365
Neutrophils from Se and Cu Deficient Cattle J.R. ARTHUR, R. BOYNE, M.J. OKOLOW-ZUBKOWSKA and H.A.O. HILL	368
Biochemical Lesions in Tissues of Cu-Deficient Cattle N.T. DAVIES, C.B. LAWRENCE, L. MILLER, A.C. DALGARNO and C.F. MILLS	371
Copper-Superoxide Dismutase and Copper Deficiency in Ruminants D.I. PAYNTER and J.D. ALLEN	374
Catecholamine Synthesis in Copper-Deficiency J.E. HESKETH	378
Aspects of Cobalt Deficiency in Ewes and Their Lambs G.A. GARTON, W.R.H. DUNCAN and B.F. FELL	382

Cobalt Deficiency in Sheep G.J. JUDSON, R.J. HANNAM, T.H. BENSON and D.J. REUTER	386
Lead Deficiency and its Effects on Growth and Metabolism M. KIRCHGESSNER and A.M. REICHLMAYR-LAIS	390
The Metabolic Lesion in Iron Deficient Muscle P. SALTMAN, Y. OHIRA, J. HEGENAUER, C.S. CHEN, L. STRAUSE and H. BEINERT	394
Hair Analysis for the Detection of Chromium Deficiency D. SHAPCOTT, J.S. VOBECKY, P.P. DEMERS, J. VOBECKY and M. CÔTÉ	397
Mineral Imbalance and Boron Deficiency R.E. NEWNHAM	400
Histologic Development of Boron Deficiency and Neoplasms W. BUSSLER	403
<u>Trace Element Environmental Contamination and Toxicity</u>	
Hair Cadmium and Lead in Learning Disabled Children B.F. HARLAND, J.P. HARWOOD and R.W. THATCHER	407
Arsenic Effects on Human Nerve Conduction J.L. VALENTINE, D.S. CAMPION, M.D. SCHLUCHTER and F.J. MASSEY	409
Iodine Contamination of Milk by Iodophor Dairy Sanitizers S.M. WHEELER, G.H. FLEET and R.J. ASHLEY	413
Airborne Particulate Lead Concentrations - Temporal and Spatial Variations in the Metropolitan Area of Perth, Western Australia B.H. O'CONNOR and W.J. CHANG	417
The Influence of Diet on Lead Toxicity J.T. SPICKETT and R.R. BELL	420
Retention by Horses of Fluorine from Calcium and Phosphorus Supplements B.J. BLANEY, R.J.W. GARTNER and T.A. HEAD	423
Effects of Fluoride Ingestion on Dairy Cattle J.W. SUTTIE	426
Low Level Determinations of Cadmium in the Environment J.R. DeLAETER, K.J.R. ROSMAN and A. CHEGWIDDEN	429
Critical Evaluation of the Significance of Internal Versus External Exposure on Cd Content of the Hair of the Laboratory Rat W.E. KOLLMER	433
¹⁰⁹ Cd Kinetics and Accumulation of Cd in the Adrenals and the Pancreas of the Rat During Chronic Exposure to Cd W.E. KOLLMER	437
Studies of a Workforce Exposed to Cadmium R. SCOTT, C. CUNNINGHAM, G.S. FELL and J. OTTOWAY	441
The Cadmium Content in Human Kidneys R. SCOTT, E. AUGHEY, M. REILLY, C. CUNNINGHAM, A. McLELLAND and G.S. FELL	445
Embryonic Uptake of Cadmium Following Maternal Exposure in Mice W.S. WEBSTER and J. CHRISTLEY	450
Rat Blood Cadmium Levels and Early Renal Lesions E. AUGHEY, R. SCOTT, G.S. FELL and C. CUNNINGHAM	453

Blood Copper, Sorbitol Dehydrogenase and Acid Phosphatase in Copper Poisoning J.S. KUMARATILAKE, J.McC. HOWELL and S.R. GOONERATNE	457
Kidney Function in Copper Toxicity in Sheep S.R. GOONERATNE, J.McC. HOWELL and J.S. KUMARATILAKE	461
Copper Toxicity and Tolerance in the Rat S. HAYWOOD	465
Selenium in Copper Toxicity in Sheep S.R. GOONERATNE and J.McC. HOWELL	468
Toxic Dietary Selenium Levels for Weanling Swine A.L. MOXON and D.C. MAHAN	471
Mineral Tolerance of Domestic Animals: A NAS-NRC Review C.B. AMMERMAN	475
<u>Trace Elements and Human Disease</u>	
Trace Elements in Human Disease, with particular reference to Copper and Zinc D.M. DANKS	479
An Acquired Form of Acrodermatitis Enteropathica Due to Longterm Lactose-Free Milk Alimentation T. MORISHIMA, S. YAGI and T. TAKEMURA	487
A Case of Alopecia in Man Associated with Zinc Deficiency B. MOMCILOVIĆ, S. HANDL, V. ZJACIĆ and M. STOJANOVIC	491
Zinc and Folate Malabsorption in Coeliac Disease S. JAMESON, O. BJÖRKLUND, L. LÖÖF and J. ULFBERG	495
Effects of Diphenylhydantoin on Zinc and Copper Metabolism R. PALM, G. HALLMANS and K. WING	499
Dermally Applied Copper Salicylates as Anti-Inflammatory Agents W.R. WALKER, S.J. BEVERIDGE and M.W. WHITEHOUSE	502
Biological Half-Life of Selenite-Selenium in some Human Diseases T. WESTERMARCK, T. RAHOLA, M. SUOMELA and A.-K. KALLIO	506
Selenium in Blood in Health and in Certain Diseases L.-O. PLANTIN, S. MEURLING, O. NYQUIST, B. STRANDVIK and R. TUNELL	510
Keshan Disease L. ZHU	514
Possible Role of Trace Elements in the Aetiology of Endemic Genu Valgum K.A.V.R. KRISHNAMACHARI	518
Hair Chromium Concentrations and Arteriosclerotic Heart Disease M. CÔTÉ and D. SHAPCOTT	521
Bromine Deficiency and Insomnia in Patients on Dialysis P.L. OE, R.D. VIS, J.H. MEIJER, F. van LANGEVELDE, W. ALLON, C.v.d. MEER and H. VERHEUL	526
Trace Element Patterns in Blood of Patients with Renal Failure R. CORNELIS, S. RINGOIR, L. MEES, N. LAMEIRE, B. WALLAEYS and J. HOSTE	530
Serum Trace Element Levels in Hepatobiliary Diseases J. VERSIECK, J. HOSTE, F. BARBIER, L. VANBALLENBERGHE, J. De RUDDER and R. CORNELIS	534

Trace Elements in Livers from a Sudden Infant Death Syndrome Survey P.E. WILSON	538
<u>Trace Element Interactions</u>	
Predicting the Effects of Molybdenum and Sulphur Concentrations on the Absorbability of Copper in Grass and Forage Crops to Ruminants N.F. SUTTLE	545
Effects of Thioanions of Molybdenum and Tungsten Upon Copper Metabolism C.F. MILLS, I. BREMNER, B.W. YOUNG and N.T. DAVIES	549
Effects of Thiomolybdate in Rats Fed a High Copper Diet J.M. GAWTHORNE, J.McC. HOWELL and R.S. WYBURN	553
The Effect of Injecting Sheep with Thiomolybdates A.J. GORDON and J.L. HILL	557
The Effect of Copper and Molybdenum on ⁷⁵ Se-Selenomethionine Metabolism in Sheep C.L. WHITE, W.G. HOEKSTRA and A.L. POPE	561
Zinc-Induced Copper Deficiency in Swine G.M. HILL, P.K. KU, E.R. MILLER, D.E. ULLREY, H.D. STOWE, T.A. LOSTY and B.L. O'DELL	564
Effect of Dietary Zinc and Cadmium on Selenium and Cadmium Availability to Rats Fed Lettuce Leaves with Varying Selenium Levels R.M. WELCH and W.A. HOUSE	568
Zinc and Vitamin A Interrelationship in Metabolism S.P. ARORA	572
Influence of Zn Status on Pb Metabolism in Rats H. SCHENKEL, H.-J. LANTZSCH and S. SCHEUERMANN	575
⁶⁴ Cu Metabolism in Infant Rats Fed Milk Enriched with Zinc, Iron and Copper B. MOMCILOVIĆ	578
⁵⁹ Fe Metabolism in Infant Rats Fed Milk Enriched with Zinc, Iron and Copper B. MOMCILOVIĆ	581
Influence of Oral Zinc Intake on Other Elements M. ABDULLA and S. SVENSSON	584
Influence of Dietary Ca on Cd Metabolism in Pigs H. SCHENKEL and B. KREHL	588
Ca, Mg and Ca/P Ratio of Rat Molars After Cd Supply G.R. WESENBURG and G. FOSSE	590
Interaction Between Nickel, Copper and Iron in Rats F.H. NIELSEN and T.J. ZIMMERMAN	593
Interaction Between Boron and Cholecalciferol in the Chick C.D. HUNT and F.H. NIELSEN	597
<u>Functions of Trace Elements</u>	
Trace Elements and Immunocompetence K.M. NAUSS and P.M. NEWBERNE	603
Brain Microtubule Assembly in Zinc-Deficiency J.E. HESKETH	613

Ethanol and Hepatic Superoxide Dismutase in Rats I.E. DREOSTI, I.R. RECORD, R.A. BUCKLEY, S.J. MANUEL and F.J. FRASER	617
Progress of Nickel Metabolism and Nutrition Research M. KIRCHGESSNER, D.A. ROTH-MAIER and A. SCHNEGG	621
Mammalian Synthesis and Degradation of Selenocysteine K. SODA, T. NAKAMURA, H. TANAKA and N. ESAKI	625
Progress in Research on Newer Trace Elements: The Metabolism of Vanadium as Investigated by Nuclear and Radiochemical Techniques E. SABBIONI and E. MARAFANTE	629
Peculiarity of Heart and Muscle Ferritins M.C. LINDER, G.M. NAGEL and M. ROBOZ	632
<u>Metallothionein</u>	
The Nature and Function of Metallothionein I. BREMNER	637
Copper-Metallothionein Metabolism in the Kidney of Brindled Mice H.W. PRINS and C.J.A. VAN DEN HAMER	645
Metallothionein m-RNA in Neonatal and Adult Rat Livers J. MERCER, T. STEVENSON, J. CAMAKARIS, I. LAZDINS and D.M. DANKS	649
Liver Copper-Binding Proteins in Disease C.J.A. VAN DEN HAMER and A.R. JANSSENS	652
Copper-Metallothionein Metabolism in Rat Hepatoma Cells Cultured <u>In Vitro</u> J.L. NOOIJEN and C.J.A. VAN DEN HAMER	656
Effects of Dietary Sulfur on Tissue Metallothionein in Rats P.D. WHANGER, S.H. OH and J.T. DEAGEN	660
<u>Aspects of Trace Element Analysis</u>	
Problems in Trace Element Analysis of Biological Systems G.V. IYENGAR	667
A Novel Method Based on Stable Isotopes for the Study of Selenium Nutrition in Man M. JANGHORBANI, M.J. CHRISTENSEN, A. NAHAPETIAN, B.T.G. TING and V.R. YOUNG	674
Serum Versus Plasma for Trace Metal Analysis N.W. ALCOCK	678
Can Skin Cells Be Used To Assay Zinc Status in Animals J. APGAR and R.M. WELCH	681
X-Ray Microanalysis of Intracellular Zinc in Human Intestinal Mucosa J.G. JONES and M.E. ELMES	684
List of Participants	689
Author and Discussion Participants Index	698
Subject Index	703

INTRODUCTORY LECTURE

1

INTRODUCTORY LECTURE

ERIC JOHN UNDERWOOD, FRs; A COLLEAGUE, MENTOR & FRIEND

C. F. Mills, Rowett Research Institute, ABERDEEN, SCOTLAND.

My Lord Mayor, Guests, Ladies and Gentlemen;

On behalf of all my fellow participants, I would first like to express gratitude to the City of Perth for all it has already done to provide us with such a congenial environment within which to hold our meetings during the next 5 days. Experience of past International Symposia on Trace Element Metabolism in Man and Animals held in Aberdeen, Madison and Munich has taught many of us to expect that we are now at the start of a stimulating and challenging if exhausting week of discussions. The success of these past meetings was due in no small measure to the kindness and hospitality extended to us that helped to maintain the informal atmosphere so essential for frank but constructive discussion of our problems. The generous welcome given to us by you, my Lord Mayor, and the kindness already shown by members of the Local Organising Committee and their families leaves us in no doubt that this is going to be an equally successful meeting.

In all our minds at this moment are thoughts of the man who should have been delivering this Opening Address. The decision to hold this meeting in Perth, Western Australia, reflected not only our wish to acknowledge the contribution made by Australasian Scientists to the topic that is of such interest to us but also to acknowledge the unique contributions of our late colleague, Professor Eric Underwood. In the interval between the idea and the event, we have lost from our company a man who in his lifetime did more than any other to emphasise to the world at large and to the scientific community in particular, the influence of essential and toxic trace element supply upon the health of man and his animals. For this reason, my pleasure at being invited to open the affairs of this meeting is tempered by the sadness we will all share throughout the week at the absence of the man who so often has guided our thoughts and activities.

Traditionally, the opening papers of past TEMA Symposia have taken the form of general reviews of recent progress. On this occasion my objectives will differ. Instead, before we embark upon this 4th Meeting, it is more appropriate we should pause to reflect upon some of the objectives and attitudes that led Eric Underwood to make such outstanding contributions in the field of trace element research and to consider how this approach, so successful in his hands, might continue to influence the effectiveness of our own future efforts.

TRACE ELEMENT RESEARCH AND ITS PRACTICAL IMPLICATIONS

When in the year 1920, the Underwood family moved to a 2,000 acre holding in the vicinity of Perth, Eric, then 15 years old, first became familiar with the difficulties faced by those Western Australians attempting to develop livestock farming in what at the time was a particularly hostile natural environment. This experience and, later, the emergence of evidence that the low productivity of the area might be partly attributable to mineral deficiencies, coloured almost all of his subsequent attitudes on the relationship between the practice and the science of agriculture. It was this background that led him as a young graduate to investigate variables influencing inorganic nutrient supply and pasture productivity in work for a Doctorate at the University of Cambridge and later, after his appointment as Animal Nutritionist working for the Department of Agriculture, Western Australia, led him to join Filmer in his studies of nutritional aspects of the aetiology of wasting diseases of cattle and sheep endemic in this and many other areas of Australasia.

The remit given to this 26 year old appointee would have daunted many. It was virtually to explain why earlier studies yielded many conflicting observations on the effectiveness of iron preparations in controlling such diseases and then to recommend more effective prophylactic measures. Although the subsequent history of the painstaking

studies leading to the finding that cobalt was the biologically effective adventitious contaminant has often been documented, such accounts usually ignore the most important personal attributes of the worker primarily responsible for this discovery. These were the clarity of his appreciation that a successful outcome to the investigation could have important practical implications and the courage of his conviction that the approach selected, although physically and at that time technically demanding, was appropriate. The road to ultimate success was hindered by problems with which some of us are once again beginning to become familiar - shortage of funds and of equipment and conflicting advice with respect to appropriate priorities for state-financed research. That so much was achieved in establishing the essentiality of cobalt for ruminants under such circumstances is its own testimony to the enthusiasm and tenacity of purpose of the man whose work paved the way for the discoveries of others that brought him equal satisfaction and pleasure - the education of the role of cobalt in cobalamin (Vitamin B₁₂) and later, identification of the biochemical defects responsible for the clinical manifestations of the disease that first excited his interest in the trace elements.

Even this brief account is sufficient to indicate the reasons why Eric Underwood's interests in the topic of the role and metabolism of the trace elements, although based upon a wide experience of their significance for health, also extended to detailed aspects of their biochemical and metabolic role in Nature. Those of his friends with a similar outlook were often made particularly aware of his intense interest in such fundamental studies. On meeting such colleagues, even after a long interval, he would often forego many of the conventional trivia of greeting and rush directly into the topic most exciting him at the time - "Hello (very briefly!) - what did you think of that excellent piece of work on". His remarks on studies for which he felt less respect were equally direct and, usually, much more succinct. The voracity with which he assimilated such newly published information never diminished. It clearly reflected his conviction that progress towards the more effective diagnosis and control of practical problems would be determined largely by the extent to which studies of those biochemical and physiological processes most sensitive to trace element deficiency or excess could be encouraged and granted adequate financial support.

SCIENTIFIC INTEGRITY AND RESPONSIBILITY

To some, the role of the trace elements in health and disease is a highly emotive subject. Although, in the context of animal health, their practical significance has been established clearly and repeatedly, much less is yet known of the influence of trace element deficiency or excess upon the health of man. Indeed, many of us have become familiar with the particular difficulty of maintaining a dispassionate appraisal of the claims sometimes made that abnormalities in trace element supply or metabolism play a primary role in the aetiology of many of man's most serious diseases or that increasing pollution of man's environment must inevitably have an adverse influence upon his health. Sometimes obscured by the dust created by the often heated discussion of extravagant claims and counter-claims lies the slowly growing body of evidence that, in some circumstances, often not fully defined, anomalies in trace element supply do indeed influence the health, development or well being of man. That, despite the vagaries of popular opinion, financial support for the conduct of trace element investigations relevant to human health has been growing steadily is largely due to the fact that we have had as one of our colleagues a man with a widely acknowledged reputation as a dispassionate arbiter of progress with a gift for distilling the essentials in his writings on the subject of the trace elements. The task of maintaining such an authoritative commentary was enormous, particularly in recent years as progress accelerated rapidly. The achievement was recognised widely. Eric Underwood's writings ultimately influenced not only aspects of the policies of national and international agencies concerned with nutrition and health but also the effectiveness with which many of us, approaching the subject for the first time, were able first to establish familiarity with the subject and, later, to develop lines of communication with other workers sharing similar interests.

I have often heard it asked what led Eric Underwood to undertake this challenging commitment. I have no doubts whatsoever. It was that he shared with many others the satisfaction and sheer pleasure to be gained from intellectually challenging scientific effort in a field in which the outcome, directly or indirectly, will influence man's ability to control nutritional disease. No one appreciated better than he, the impact of trace element deficiency upon animal and human health in so many parts of the world. But