Human growth: its assessment, evaluation and variation

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Submission for the Higher Doctorate Degree of

Doctor of Science (DSc)

Human growth: its assessment, evaluation and variation

by

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Professor of Human Biology, Loughborough University

February 2018
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Prologue

James Tanner (1920-2010) was widely recognised as the leading figure in auxological research from the 1950s to the 1990s and the field is replete with his eponymous contributions (e.g. Tanner pubertal stages; Tanner-Whitehouse skeletal maturity assessments). Having successfully completed an MSc degree in Human Biology at Loughborough University in 1973 I entered James Tanner’s Department of Growth and Development at the Institute of Child Health (ICH) in London University to undertake my doctoral studies under his supervision. Tanner had been appointed as the first Professor of Child Health and Growth at the ICH in 1963 and by 1973 he was the leading researcher in human growth and development in Europe. His Department of Growth and Development was the primary clinical and research centre for human growth research in the UK - a position it maintained for almost 40 years. In this environment I was exposed to research projects covering both normal and abnormal growth using data emanating from ongoing and newly created longitudinal growth studies (e.g. Harpenden, International Children’s Centre London, Royal Hospital School, Chard) and clinical growth data collected primarily by myself and RH Whitehouse in the Growth Disorder Clinics held twice weekly under Tanner’s directorship at the Hospital for Sick Children, Great Ormond Street. Whilst the early part of my career (1973-1983) was spent in this clinical research environment I have chosen to concentrate on my output relating to normal growth, its assessment, evaluation and variation because it is the non-clinical arena in which I believe my contributions have been significant and internationally recognised.

The research papers submitted for the degree of DSc demonstrate a sustained contribution to the research field of human growth and development over more than 40 years. The significance of my publications, my contribution to the field, and my international standing have been recognised by over 13,500 citations, invitations to give numerous keynote lectures at international meetings, visiting fellowships and professorships at leading international universities, Fellowship of the Royal Society of Biology, membership of Executive Committees of the leading international societies in my field of research, and editorship, associate editorship or membership of the editorial boards of the leading international Human Biology and Auxology journals. I have been invited to give the eponymous “Tanner Lecture” at international congresses in Mexico City (2009) and Slovenia (2014) and was the inaugural recipient of the James Tanner Memorial Medal by the Society for the Study of Human Biology in Oxford in 2014.
Publications

Books


Chapters in edited volumes


17. **Cameron N**. Adulthood and development maturity. In: Ulijaszek SJ, Johnston FE,


Articles in Peer Reviewed Journals


5. Cameron N. Het Voorspellen van de Volwassen Gestalte. (The prediction of adult height.) Hermes(Leuven),XIII; 167-176. 1979


Gonadotrophin response to LH-RH in boys with delayed growth and adolescence. Archives of Disease in Childhood, 56;552-556. 1981


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41. Yach D, Cameron N, Padayachee N, Wagstaff L, Richter L, Fonn S, MacIntyre J, De Beer M. Birth To Ten: Child Health in South Africa in the 1990's, Rationale and
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Methods of a Birth Cohort Study. Paediatric and Perinatal Epidemiology, 5; 211-233. 1991


43. Cameron N. Human growth, nutrition and health status in Sub-Saharan Africa. Yearbook of Physical Anthropology, 34; 211-250. 1991


48. Cameron N. Assessment of growth and maturation during adolescence. Hormone Research, 39, (Suppl. 3); 9-17. 1993


50. Cameron N. The Tanner-Whitehouse II skeletal maturity method: Rationale and applicability. Clinical Pediatric Endocrinology, 2(Suppl. 1); 9-18. 1993


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268. 1999


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82. Cameron N. Physical growth in a transitional economy: the aftermath of South African apartheid. Economics and Human Biology 1(1);29-42. 2003

83. Cameron N, Pettifor J, De Wet T, Norris S. The relationship of rapid weight gain in infancy to obesity and skeletal maturity in childhood. Obesity Research 1; 457-460 2003


104. Griffiths PL, Rousham EK, Norris SA, Pettifor JM, Cameron N. Socio-economic status and body composition outcomes in urban South Africa. Archives of Disease in Childhood 93; 862-867. 2008.


115. Sheppard ZA, Norris SA, Pettifor JM, Cameron N, Griffiths PL. Approaches for assessing the role of household socioeconomic status on child anthropometric measures in urban South Africa. American journal of Human Biology 21(1); 48-54. 2009.

116. Jones LL, Griffiths PL, Norris SA, Pettifor JM, Cameron N. Age at menarche and the evidence for a positive secular trend in urban South Africa. American Journal of Human Biology 21(1);130-132. 2009.


121. Willey BA, Cameron N, Norris SA, Pettifor JM, Griffiths PL. Socio-economic predictors of stunting in pre-school children. South African Medical Journal


139. Hawley NL, Rousham EK, Johnson W, Norris SA, Pettifor JM, Cameron N. Determinants of relative skeletal maturity in South African children. Bone. 50(1); 259-64 2012


149. Friend-du Preez N, Cameron N, Griffiths P. "So they believe that if the baby is sick you must give drugs..." The importance of medicines in health-seeking behaviour for childhood illnesses in urban South Africa. Social Science and Medicine. 92:43-52. 2013.


153. Cameron N. Body mass index and body mass index charts. Highlights 21(3); 20-23. 2013


Summary of work submitted

Human growth: its assessment, evaluation and variation

In this submission I have chosen to divide my output into three parts; (1) the assessment and evaluation of human growth and (2) normal human growth and its variation with particular reference to South Africa and (3) the developmental origins paradigm. I have accumulated in excess of 300 published contributions in the field of human growth so for the sake of brevity I have chosen to include copies of 30 publications to support this submission. These publications represent mostly internationally reviewed articles and one book chapter. The various textbooks, most notable covering anthropometry, skeletal maturity, and research methods in the general field of human growth and development, that are used internationally by practitioners and students alike, have not been included in this submission yet they form a significant contribution to the field of human growth and development. The TW2 skeletal maturity method has been cited over 2,500 times and my reference work on anthropometric measures almost 500 times indicating the frequency with which these methods have been sued by growth researchers.

The superscripted numbers relate to the full publication list in my CV (with ‘B’ denoting Books and ‘C’ denoting book Chapters. Other superscripted numbers denote peer reviewed papers) Bold numbers in brackets denote those contributions reproduced as part of this submission.

Part 1. The assessment and evaluation of human growth and development

(Publications 1-11)

Anthropometry (submitted refs 1-2): In the early part of my sojourn at the ICH it became apparent that the literature describing the anthropometric methods used to evaluate growth were primarily based on treating the child as a small adult. The specific modifications to the methods required to deal with the growing body had not been documented. From 1978 to 1988 I published a series of papers, book chapters and a textbook that addressed this lack of description. These included not only original contributions but also revisiting and modernising some established modus operandi, such as the International Biological Programme methods. These core publications have become reference standards within the field of the anthropometry of growth having been cited in over 1200 publications; The Measurement of Human growth (1984) has received in excess of 450 citations, and The Methods of Auxological Anthropometry, published within two chapters in the reference work “Human Growth” in the 1st and 2nd editions (1978, 1984) (1), have received over 750 citations. I have also chosen to include the latest incarnation of anthropometric methods with a 2013 invited review for the American Journal of Human Biology as part of a series of methods papers that form the basis for fieldwork recommendations.

Skeletal maturity (refs 3-4): I have also been instrumental in the development of the Tanner-Whitehouse methods for the assessment of skeletal maturity and the prediction of adult height. As with anthropometry it was evident in the early 1970s that the first bone specific scoring method to assess skeletal maturity, the Tanner-Whitehouse method (TW1), which had been developed a decade previously, was in need of a major revision and update. I achieved this with the joint publication of the TW2 method in 1983 and again 20 years later I worked directly with James Tanner on a further update to produce TW3. These works are fundamental to the characterisation of the skeletal maturity of children; they are used in paediatric and research scenarios globally, and have been cited over 2,500 times. A variety of other publications have dealt with measurement and evaluation issues in human growth and
the assessment of maturation (3,4). My internationally recognised expertise in the field of the measurement of human growth is reflected in the seven entries I have authored in The Cambridge Encyclopaedia of Human Growth and Development published in 1998; these include contributions on Measurement and Assessment; Radiographic Assessment, Fat and Fat Patterning; Adulthood and Developmental Maturity; Skeletal Development; and Epiphyseal Fusion^C14-C20.

Growth charts (refs 5-8): Throughout my research career the question of using the most appropriate reference charts to sensitively and specifically appraise the normality or otherwise of the growth of children has been a recurring question. I worked extensively with the UK growth charts, both general and clinical, produced by Tanner and Whitehouse in the 1960s and 1970s^7,23,32,45,76-78,81,106,117,131,153. My work in South Africa in the 1980s and 1990s resulted in publications in which I discussed the use and value of national and international growth charts^23,32,45,60(5,6) and my acknowledged expertise in this discussion resulted in me being invited to join the WHO Working Group on the Growth Reference Protocol that discussed and developed the latest WHO growth standards (2007) (7,8). These standards are now used globally to assess the growth and development of infants, children and adolescents from birth to adulthood.

Age estimation: The relationship between maturity and age has been an area of interest to successive governments as they attempt to determine whether unaccompanied minors entering the UK are entitled to various welfare benefits. This discussion has been ongoing since the mid-1970s when the influx of Ugandan Asians was prompted by Idi Amin’s regime. I was first approached at that time to proffer my opinion in a paper in Science and Public Policy ^17(9). Most recently with the influx of migrants to continental Europe this area of Auxology has again become relevant and my expertise has again been sought to provide a scientific background to the relationship between maturity and age^164,168 (10,11).

Other publications listed in my CV cover different aspects of the assessment and evaluation of human growth ranging from the development of new assessment methods^B7,C7,C9,C11,C21,C24-C31,C34,C36,C38 to the variation in evaluation of the process of growth and development from using both established and novel methods of data acquisition and analysis^B7.


(Publications 12-21)

Normal growth (refs 12-15): My earliest publications (1973-1983) related to research questions concerning both normal and abnormal growth. My PhD research documented the secular trends in growth during the 20th century revealed by an extensive analysis of London County Council data collected from cross-sectional surveys conducted from 1904 to 1966^4 (12). This was to be the first of a number of papers spanning the next 30 years that documented secular trends in the UK and South Africa with evidence from pre-existing and newly initiated growth studies and skeletal collections^29,30,35,38,40,44,57,96,101,116,119,127. In addition, I tackled a number of specific questions relating to various aspects of the pattern of human growth: the relationship between body size and menarcheal age in 1976^2; the existence, timing, duration and magnitude of the mid-growth or juvenile spurt was elucidated in 1980^13; the pattern of change in VO2max during adolescence in 1981^12, the growth of limb segments^18(14) and the relative importance of the growth of the anatomical leg to secular changes in height in Japan 1982^19(15).
South Africa (refs 16-21): I spent from 1984 to 1997 in the Department of Anatomy and Human Biology in the Medical school of the University of the Witwatersrand, South Africa. During this time I initiated three longitudinal growth studies at Vaalwater, Ubombo, and in Soweto-Johannesburg36,38,40-46,49,51,52,55,58,63,66 (16, 21). A major part of my raison d’être for working in South Africa was to make contributions in the human growth and development of the disadvantaged black population. Prior to my research there had been few South African studies of the normal growth of such children; most studies had been investigations initiated by concerns over maternal and child health and malnutrition and almost all were of a cross-sectional design and had been conducted in urban areas. It was clear in 1984 that the end of apartheid was in sight and as a result the draconian laws, known as the “pillars of apartheid”, that controlled freedom of residency, occupation, education, health care, and marriage were breaking down. The South African census of 1983 predicted that 14 million black Africans would move into urban areas by the year 2000 and that urban areas would double in size by 2010. There was a clear and obvious need for baseline information on the growth of black children for two reasons (1) to monitor the effects of almost 40 years of disadvantage under apartheid and (2) to be able to monitor the positive changes that might result in a post-apartheid, non-racial, democratic South Africa. Vaalwater and Ubombo were two rural areas with different characteristics38,40,43-46,49,51,52,63. The former was a farming area, mainly growing tobacco, in the northern Transvaal not far from the Botswana border and the latter a traditional rural area of subsistence and cattle farmers in the Eastern Transvaal near the Mozambique border. I initiated longitudinal studies in both areas and published a series of articles that formed the first baseline data on normal growth and pubertal development of rural black children (17). The third longitudinal study was a birth cohort study called Birth to Twenty (Bt20) that was specifically initiated to investigate the effect of the urban environment on child health and growth. Bt20 started on late April 1990 and is now recognised as the longest running and most detailed study of child growth and health in sub-Saharan Africa. It forms one of the COHORTS studies and is widely recognised for the contribution it has made to our understanding of the growth of African children in rapidly urbanising environments 36,41,42,55,58,65,68-70,74,75,82,83,87,89,91,94-98,101,104,106,111,115,116,118-121,128,130,132,136,138,139,141,148,149,157 (18-20).

In précis, these studies have documented the differences in the pattern of growth exhibited by black African and White children towards the end of apartheid and subsequently the positive secular trends that have occurred (16-21). Importantly publications relating to the increased rates of pubertal development (menarche, puberty), skeletal maturity (bone age) and growth have been landmark studies38,40,44,49,51,52,57,63,16,119,127,157,162. In addition, and subsequent to my departure from South Africa in 1997, the Bt20 study has been used for a variety of landmark papers concerning child health and growth in the global setting of developing and transitional countries 96,101,140.

Part 3: The developmental origins paradigm

(Publications 22-30)

Developmental Origins of Health and Disease (refs 22 – 30): My return to the UK in 1997 coincided with growing interest in the developmental origins of non-communicable diseases of lifestyle (NCDs) advocated by the late Professor David Barker. Barker proposed that the pattern of fetal growth was in response to the intrauterine environment and that insult during this time resulted in adaptation by the fetus which led to increased post-natal risk for NCDs. Some of my papers during this time explored the existence of critical periods in human growth during infancy and childhood80 (30) and, combined with studies of infant growth from Bt20,
were significant in identifying early infant growth as being critical in the acquisition of risk for NCDs. Within the developmental origins paradigm, the existence of significantly increased risk for NCDs amongst South Asians has received considerable attention. In 2007 I was involved in the development of another birth cohort study in Bradford (Born in Bradford; BiB) to specifically address the question of the aetiology of NCD risk in the bi-ethnic population of that city. Through analyses carried out by two of my PhD students we have been able to explore the growth of this mixed ethnic sample during intrauterine life and infancy. The importance of this work is in understanding the greater risk that South Asians display in relation to the acquisition of NCDs.

I believe that this submission represents published work of high merit in the research fields of human growth and development/Auxology. The publications indicate both an internationally recognised expertise in my field of research and a sustained contribution to understanding within this field.
Statement on publications submitted

Only a small subset of my 300 publications is included in this submission. The submitted papers relate primarily to the key research areas summarised in the preceding section: anthropometry, skeletal maturity, growth charts, age estimation, normal growth and its variation, South Africa, Developmental Origins of Health and Disease. In all cases the publications were solely or jointly prepared by myself and PhD students or research associates and collaborators. All the papers benefitted fully from my intellectual input but my contribution to each paper varied from 100% of the actual writing and preparation of the manuscript where I am first author to a significant but lower percentage where I am a co-author or senior author.

The specific papers submitted are tabulated below (Refs 1-30). The “CV Refs” refers to the numbering my list of publications within my Curriculum Vitae.

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<td><strong>Anthropometry</strong></td>
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<td><strong>Skeletal maturity</strong></td>
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<td>4</td>
<td>50</td>
<td>Cameron N. The Tanner-Whitehouse II skeletal maturity method: Rationale and applicability. Clinical Pediatric Endocrinology, 2(Suppl. 1); 9-18. 1993</td>
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<td></td>
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<td><strong>Growth charts</strong></td>
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**Normal growth and its variation**

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**South Africa**

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<td>19</td>
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<td>Cameron N, De Wet T, Ellison GTH and Bogin B. Growth in height and weight of South African urban infants from birth to five years: the Birth To Ten Study. American Journal of Human Biology, 10 (4); 495-504. 1998</td>
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**Developmental Origins of Health and Disease**

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<td>24</td>
<td>74</td>
<td>Crowther, NJ, Trusler, J, Cameron, N, Toman, M, Gray, IP. Relation between weight gain and beta-cell secretory activity and non-esterified fatty</td>
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<td>28</td>
<td>156</td>
<td>Norris T, <strong>Cameron N</strong>. Investigating the relationship between prenatal growth and postnatal outcomes: A systematic review of the literature. Journal of Developmental Origins of Health and Disease 4(6); 434-441. 2013</td>
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<td>29</td>
<td>159</td>
<td>Norris T, Tuffnell D, Wright J, <strong>Cameron N</strong>. Modelling foetal growth in a bi-ethnic sample: results from the Born in Bradford (BiB) birth cohort. Annals of Human Biology. 41(6);481-487. 2014</td>
</tr>
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<td>30</td>
<td>80</td>
<td><strong>Cameron N</strong>, Demerath EW. Critical periods in human growth: relationships to chronic disease. Yearbook of Physical Anthropology 45;159-184. 2002</td>
</tr>
</tbody>
</table>
Submitted publications
Appendix 1

Abstracts of Conference Proceedings


27. **Cameron N**, Wolmarans L, De Wet T, Becker PJ. Growth characteristics of the Birth To Ten subjects. Urbanisation and Health, 17(1); 34-47. 1993

28. Yach D, Richter L, **Cameron N**, De Wet T, Von Schirnding YER. Birth To Ten: Methods of a birth cohort study (Part 1). Urbanisation and Health, 17(1); 4-13. 1993

29. Richter LM, Yach D, **Cameron N**, De Wet T, Anderson A. Birth To Ten: Methods of a birth cohort study (Part 2). Urbanisation and Health, 17(1); 14-25. 1993


32. Gordon PS, **Cameron N**. An investigation of the adolescent growth spurt as a compensation phenomenon in the growth of children in developing countries. American Journal of Physical Anthropology, Suppl.16; 97. 1993


34. McKee JE, **Cameron N**. Fluctuations in bioelectrical impedance during the menstrual cycle. American Journal of Physical Anthropology, Suppl.16; 143. 1993

35. **Cameron N**. The interaction of heredity and environment in the control of human growth and development. American Journal of Physical Anthropology, Suppl.18; 64. 1994


40. Ellison GTH, **Cameron N**, Wagstaff L, De Wet T. Weight grain during the first year of the Birth To Ten study. The interaction between morbidity and infant feeding patterns. Annals of Human Biology, 23;180. 1996


46. Cameron N. The relationship between stunting at two and growth from birth to five years in urban African children from Soweto, South Africa. American Journal of Human Biology, 10; 118. 1998

47. Cameron N. Changing prevalence of childhood obesity in developing countries. International Journal of Obesity, 22, Suppl. 4; S1. 1998

48. Trusler J, Crowther NJ, Cameron N, Gray IP. Weight gain, beta-cell secretory activity and insulin sensitivity in seven-year-old children. Diabetologia, 42(1);220 1999


50. Cameron N. The use and interpretation of reference charts for the assessment of nutritional status. American journal of Human Biology 11(1);109 1999

51. Cameron N. The variability of growth during childhood as a reflection of prenatal stress and adult morbidity. HOMO, 51; S16. 2000


53. Cameron N, Pettifor J, De Wet T, Norris S. Predictors of body composition at 9 years from anthropometric data collected at 5 years in African children: can school entry be a critical time for predicting pre-adolescent body composition? Obesity Research 9(3);138S 2001

54. Cameron N, Pettifor J, de Wet T, Norris, S. Catch-up growth in infancy predicts overweight and obesity at 9 years: identifying the potentially obese adolescent. Obesity Research 9(3);154S 2001
55. Crowther NJ, Cameron N, Trusler J, Gray IP. Catch up growth and glucose tolerance in children. Diabetologia, 44(1);979 2001

56. Norris SA, Vidulich L, Cameron N, Pettifor JM. The bone mass pattern in 9-year old South African black children is similar to that found in their mothers, but is different to those in African-Americans. Journal of Bone and Mineral Research 16(1); S2316 2001

57. Norris SA, Pettifor JM, Cameron N, De Wet T, Vidulich L, Cumin E. Bone mass differences between 9-year old black and white, urban South African children. Bone 28(5); S128 2001


63. Cameron N. Catch-up growth increases risk factors for obesity in urban children in South Africa by one year of age. International Journal of Obesity 25(Suppl. 2); S48. 2001


65. Cameron N, Pettifor J, de Wet T, Norris S. Predictors of body composition at 9 years from anthropometric data collected at 5 years in African children: can school entry be a critical time for predicting pre-adolescent body composition? Obesity Research 9 (Suppl 3); 138S 2001


67. Wright MM, Griffiths P, Cameron N, Norris SA, Pettifor JM. The association between

68. Cameron N, Pettifor J, de Wet T, Norris S. Catch-up growth in infancy is not related to advanced skeletal maturity in childhood. American Journal of Human Biology 14(1); 105-6 2002.


92. Varela-Silva MI, Bogin B, Mendes V, Fragoso I, Cameron N. Positive and negative secular trends in the height of Cape Veredian boys and girls American Journal of Human Biology. 17(2); 260. 2005

93. Cameron N. Growth patterns during infancy and childhood as risk factors for the metabolic syndrome. American Journal of Physical Anthropology. 40(Suppl.); 82. 2005


95. Willey BA, Griffiths P, Cameron N, Norris SA, Pettifor JM. Socio-Economic status, social support and stunting in pre-school years in an urban South African sample from 1990. Epidemiology 16; S149. 2005.

21 (S1); S124. 2006.


109. Cameron N, Griffiths PL, Norris SA, Pettifor JM. Tracking of BMI from early to late childhood. In Developmental Origins of Health and Disease (DOHaD) Conference, Perth,


121. Fragoso I, Varela-Silva M I, Cameron N. Health outcomes of Cape-Verdean migrants to Lisbon. A historic note on colonialism in Portugal. American Journal of Physical Anthropology 135(S46); 98. 2008


125. Jones LL, Griffiths PL, Norris SA, Cameron N. Childhood growth trajectories and body composition are the most sensitive indicators of pubertal timing in urban South Africa. Annals of Human Biology 36(5); 657-658. 2009.


130. Cameron N. The contribution of the Fels longitudinal study to European auxology. American Journal of Physical Anthropology 144(S52); 101. 2011.


Appendix 2

Book Reviews


Appendix 3

Articles in Non-Refereed Journals

Cameron N. The measurement of height and weight and the use of growth charts. Graves Medical Audiovisual Library. 1982

Cameron N. The measurement of sitting-height, triceps and subscapular skinfolds and upper-arm and head circumference. Graves Medical Audiovisual Library. 1982

Cameron N. Medical Students in South Africa - Where to? The Leech, 57(1) 15-16. 1988

Cameron N. Human Growth in South Africa - Where to? The Leech, 57(2);40-41. 1988

Cameron N. The evaluation of human growth and development. Pedmed, 3(1);3-10. 1989


Cameron N. Departing thoughts of a visiting fellow. Almanac of the University of Pennsylvania, 37(20);3. 1991


Cameron N. Birth To Ten. Arena, 1,(3);16-17. 1994

Cameron N. Obituary: Frank Tardrew Falkner. The Times October 2nd 2003