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President's Column

JAK KELLY

The Presidents Column for this issue is in the form of a poem for the new year.

THE RHYME OF THE ANCIENT SCIENTIST

It was an ancient scientist
Who one day said to me
'I see from your computer screen you model in 3D
When I was young we did not hope such wonders ere to see
For all we had was real, not virtual, reality.'

I really didn't want to know
I'd heard it all before
From lecturers who rambled on about the days of yore,
Of log tables and slide rules and such arcane devices
And knew nothing of the joys of Tomographic slices.

I fiddled with the format
And wished he'd go away.
Alas, it was an idle hope, I saw he meant to stay.
'When I was young', he whittered on, on reminiscence bent,
'I hankered not for fame nor gold but to experiment.'

My teachers said 'The lad is bright
And quite good at debate.
You should enrol him in the law at which he'd be first rate.
He'd earn a damn good living with the muscles of his jaw.
No one makes money out of science, as you have heard before.'

But I was young and waterproof
And had made up my mind
That neither to the arts nor law was I enough inclined.
I had enjoyed in argument to see opinions swayed,
But what was that compared with how the universe was made.

He told me about where he'd been
And all the things he'd done
'The pay was marginal' he said, 'But, by God, it was fun.
We really were like amateurs, there to enjoy the game.
It mattered less who won or lost, the science was the same.'

'How could you be such dilettantes?
And let your science serve
The evil ends of powerful men, out to control the world.
We now are more responsible. We worry about things
Like, will the earth be boiling hot and balanced yang and ying.

We are now more professional
In how our labs are run
And who would fund a grant if told 'I'm doing this for fun.'?
There is nothing wrong, of course, with feelings of elation,
Provided that they don't reduce our score in the citations.

'I read upon a gravestone once'
He smiled and looked at me,
As you are now so once was I, as I am now you'll be.
I hoped perhaps it might be true, when first I came in here.
And at the door he paused and said 'A Happier New Year'

The Royal Society of NSW – 100 Years Ago

JAK KELLY

Extract from the Presidential Address by C.O. Burge published in the Journal and Proceedings of the Royal Society of NSW Volume XXXIX (1905) pp. 1–22

Yet, among the young men of our day what are the names of Kelvin, of Lodge, of Rayleigh, of Dewar, of others, beside that of a famous cricketer, or of the man who can kick a ball further or straighter than another? We may allow that mental culture cannot stand alone, it must be the outcome of sufficient physical training. The old maxim 'Mens sana in corpore sano' is ever true, but are we not overloading the latter part of the prescription? The traditional Irishman is sneered at for regarding fighting as an end, and not a means, but are not the Australians earning the reputation of confounding means and ends, in an even more absurd way? The combination is as old as Plato who laid down music and gymnastics as the twin bases of education . . . but the gymnastics were regarded as means only, for the double purpose of efficiency in war, and for the training of the body, so that it should be intellectually vigorous.

The man of science is unappreciated, because his gifts are unsought, and when conferred, are rapidly rendered commonplace by constant use, and often that use does not become available for some years after the invention has left the authors brain.

It has been well said that the question is not whether a man has gone through the university, it is whether the university has gone through him. Training in habits of exact observation and intelligent inference is wanted, not that interest which is expressed by the observation of a man of unscientific temperament, who once spoke of a proposition in Euclid, as a happy ending to a mildly exciting plot.

Not withstanding the neglect, until latterly, of science in engineering, great strides have been taken, perhaps the greatest, in recent times, have been in connection with light; mechanical contrivances and energy, through the medium of electricity; and the disposal of refuse of cities. As to light, there is the question which is more one for the anatomist than the engineer, whether the human eye is developing the power to withstand, without injury, the intense brightness provided by modern electrical and gas engineers.

A Comparison of Seed Germination Calculation Formulae and the Associated Interpretation of Resulting Data

M.A. KADER

Abstract: Much experimentation concerns itself with the level and rapidity of germination, yet analyzing and interpreting results can be a difficult task due to the vague nature of some seed germination data. This paper examines a number of data analysis methods adopted in seed germination and emergence tests. What constitutes a good result in one experiment may not be the same in another and this depends, to a large extent, on the data analysis method used. A review of these methods reveals the different interpretations that can be drawn from applying different formulae. Not just the final germination percentage, its mean time or spread, but also the 'high' and 'low' germination events have an impact on the parameters calculated. This paper shows that the Germination Index (GI) is the analysis method that best describes the germination percentage/speed relationship. Germination percentage and mean time alone are not sufficient in representing a seed lot in terms of its germination activity in a given time frame.

Keywords: germination data, data validity, germination speed, emergence rate

INTRODUCTION

The term germination in the seeds of higher plants (Angiosperms) refers to the protrusion of a root or shoot from the seed coat, while emergence is the visible penetration of the shoot above the soil surface (Hadas and Russo 1974, Hadas 1976, Benech Arnold et al. 1991).

In order that a seed can germinate, it must be placed in environmental conditions favourable to this process (Craufurd et al. 1996). Among the conditions required is an adequate supply of water, a suitable temperature range and, for some seeds, light (Collis-George and Williams 1968, Levitt 1980, Long and Woodward 1998). The result is measured in terms of the extent to which seeds have germinated (the final germination percentage attained) and the speed with which the germination process has ended. Frequently, though, other parameters represent significant factors from agronomic, planning or physiological perspectives (Jones and Sanders 1987, Esechie 1994, Kader et al. 1998, Kader 1998, Kader et al., 1999, Kader, 2005).

The length of time elapsed between the first seed to germinate and the last, the variation in germination speed and the timing that the majority of seeds germinate all have impacts on diverse cultural operations like fertilising, harvesting and field maturity of crops (Roberts 1981, Washitani and Saeki 1986, Kader and Jutzi 2001). 'High' (the time at which the majority of seeds germinate) and 'low' (the time at which the minority of seeds germinate) (Kader et al. 1998) germination events are also important indicators of seed vigour and stress resistance (Kader and Jutzi 2002). These data, from an experimental standpoint, also have a significant impact on statistical analyses (Bland and Altman 1995, Legendre and Legendre 1998, Johnson 1999).

A large proportion of experiments relating seed germination to time and rate calculations face difficulty in interpreting and analysing results (Finch-Savage et al. 1998, Trudgill et al. 2000, Grundy et al. 2000). The methods used to evaluate seed germination and emergence are analytical or graphical (Scott et al. 1984), but germination data have several characteris-

tics that distinguish them from other data frequently collected in plant research. Germination is considered to be a qualitative developmental response of an individual seed that occurs at a point in time, but individual seeds within a treatment respond within different times (Harper and Benton 1966, Orchard 1977, Scott et al. 1984, Kader 1998). This leads to a situation where the final germination percentage alone is not sufficient for reporting results due to the lack of ability to compare two sets of data (one lot of seed may have germinated well before the other, but both attained the same final germination percentage). This has been indicated as a set back in previous work relating seed treatments to the germination pattern of seed lots (Timson 1965, Todd and Webster 1965, Harris and Wilson 1970, Thompson, 1974) leading to the development of a number of germination measurement techniques (Heydecker 1966, Scott et al. 1984, Carberry and Campbell 1989).

This review compares various methods of analysing, representing and interpreting germination data. It draws comparisons between the various methods and identifies the most widely encompassing method correlating final germination with time.

MATERIALS AND METHODS

A review of seed germination analysis methods in the literature was conducted and revealed the methods shown in Table 1 as the major parameters used in germination studies. These germination calculation methods fall broadly into the following 3 categories.

1. Data analysis formulae interpreting the final germination percentage attained
2. Data analysis formulae interpreting the time taken to achieve seed lot germination
3. Data analysis formulae correlating 1 and 2

The various methods were compared for accuracy and representation using the germination data of Kader et al. (1998, 1999) and Kader and Jutzi (2001, 2002), as well as hypothetical germination data (see details below), illustrating time-based differences in the 3 different categories below.

1. Accuracy of representation of germination percentage/time correlations
2. Accuracy of representation of time spread of germination
3. Accuracy of representation of the uniformity of seed lot germination

The problem comes from observations from field, laboratory and growth chamber experiments conducted between 1993 and 2002 involving monocotyledons (*Sorghum bicolour* and *Pennisetum glaucum* L. R. Br) and dicotyledons (*Acacia farnesiana* and *Acacia saligna*). These two groups represent both hypogeal and epigeal germination in a field crop and tree species, respectively (ISTA 1993). Hypothetical data was employed where necessary (detailed in each scenario – see Tables 2 to 9 below). The parameters used to compare the germination data for representation and accuracy were as follows.

1. Final Germination Percentage (FGP)
2. Mean Germination Time (MGT)
3. Germination Index (GI)
4. Coefficient of Velocity of Germination (CVG)
5. Germination Rate Index (GRI)
6. First Day of Germination (FDG)
7. Last Day of Germination (LDG)
8. Time Spread of Germination (TSG)

The details, measurement units and calculation methods of each parameter are shown in Table 1, with a base germination period of 10 days being used and applied to 4 seed lots.

RESULTS AND DISCUSSION

The results of Tables 2–9 reveal a wide variation between germination data based on the time spread of germination as well as its final percentage. FGP only reflects the final percentage of germination attained and provides no pic-

ture of the speed or uniformity of germination. Table 2 shows that the 4 seed lots tested all attained an FGP of 95%, but had varying time spreads of germination.

MGT is an accurate measure of the time taken for a lot to germinate, but does not correlate this well with the time spread or uniformity of germination. It focusses instead on the day when most germination events occurred. As seen from Table 3, seed lots started germination on the same day and attained the same FGP, but had varying MGT values. Table 4, on the other hand, shows the same TSG value for the 4 seed lots, a different FGP, yet the same MGT. This means that seed lots can germinate across a different spread and attain a different final germination percentage, yet have the same mean germination time.

GRI calculations merely show the percentage of germination per day, so the higher the percentage and the shorter the duration, the higher the GRI. This parameter lacks any correlation with the 'high' and 'low' germination days as it spreads the percentage evenly across the time spread. Table 4, shows seed lots with a CVG of 50, but GRI values ranging from 18.4 to 50.0.

CVG does not focus on the final percentage of germination, but places emphasis on the time required for reaching it. The details of time (first day, last day and time spread) are not taken into account as the time is averaged. Table 5 shows seed lots with the same FDG, LDG and TSG, but different CVG values. This means that time-based measurements, not correlated with the FGP, are not a very useful representation of the overall seed germination activity. Starting germination and ending it at the same time is not sufficient enough to produce a uniform CVG and is therefore misleading.

First day, last day and time spread of germination are good measures of when the first germination event started, when the last event occurred and the time between the two, but, again, lacks any correlation to the final germination attained. Tables 6, 7 and 8 highlight this. Whether the TSG is 1 or 7 days, and regardless of the FGP, seed lots could still start germination and end it on similar days (i.e., same FDG and same LDG values).

The GI appears to be the most comprehensive measurement parameter combining both germination percentage and speed (spread, duration and 'high/low' events). It magnifies the variation among seed lots in this regard with an easily compared numerical measurement. As an example, in Table 3, seed lots all attained an FGP of 95% over 3 days. The lot with 31.6% over 3 days had an MGT of 1.9 days and that with 47.5% over 2 days had an MGT of 1.5 days. This is a difference of merely 0.4 days despite the fact that on each occasion the second seed lot germinated 15.9% more. The GI, on the other hand emphasises this difference more clearly where the GI for the 3-day time spread is 853.2 and that for the 2-day time spread is 905.5, a difference of 52.3 units.

In conclusion, the use of germination data analysis methods is prone to mis-interpretation if germination percentage, speed, spread and concentration are not taken into account in one measurement. In the context of the parameters tested in this investigation, it appears that the GI is the most accurate in this regard. An alternative would be to use a number of parameters when reporting germination trial results and place these in one single formula. This will be addressed in a subsequent paper.

Germination Parameter	Symbol	Unit	Formula for Calculation	Description of Formula	Notes & Reference
Final Germination Percentage	FGP	%	FGP=Final no. of seeds germinated in a seed lot $\times$ 100		The higher the FGP value, the greater the germination of a seed population. Scott et al. (1984)
Mean Germination Time	MGT	day	$\text{MGT}=\sum f \cdot x / \sum f$	f=Seeds germinated on day x	The lower the MGT, the faster a population of seeds has germinated. Orchard (1977)
First Day of Germination	FDG	day	FDG=Day on which the first germination event occurred		Lower FDG values indicate a faster initiation of germination. Kader (1998)
Last Day of Germination	LDG	day	LDG=Day on which the last germination event occurred		Lower LDG values indicate a faster ending of germination. Kader (1998)
Coefficient of Velocity of Germination	CVG	—	$\text{CVG}=N_1 + N_2 + \cdots + N_x/100 \times N_1T_1 + \cdots + N_xT_x$	N=No. of seeds germinated each day, T=No. of days from seeding corresponding to N	The CVG gives an indication of the rapidity of germination. It increases when the number of germinated seeds increases and the time required for germination decreases. Theoretically, the highest CVG possible is 100. This would occur if all seeds germinated on the first day. Jones and Sanders (1987)
Germination Rate Index	GRI	(%/day)	GRI=G1/1 + G2/2 $+\cdots+$ Gx/x	G1=Germination percentage $\times$ 100 at the first day after sowing, G2=Germination percentage $\times$ 100 at the second day after sowing	The GRI reflects the percentage of germination on each day of the germination period. Higher GRI values indicate higher and faster germination. Esechi (1994) after modification.

Table 1. Description of various parameters used to study seed germination.

Continued from previous page.

Germination Parameter	Symbol	Unit	Formula for Calculation	Description of Formula	Notes & Reference
Germination Index	GI	—	GI=(10×n1) + (9×n2) + ⋯ + (1×n10)	n1, n2 …n10 = No. of germinated seeds on the first, second and subsequent days until the 10th day; 10, 9 … and 1 are weights given to the number of germinated seeds on the first, second and subsequent days, respectively	In the GI, maximum weight is given to the seeds germinated on the first day and less to those germinated later on. The lowest weight would be for seeds germinated on the 10th day. Therefore, the GI emphasizes on both the percentage of germination and its speed. A higher GI value denotes a higher percentage and rate of germination. Bench Arnold et al. (1991)
Time Spread of Germination	TSG	day	TSG=The time in days between the first and last germination events occurring in a seed lot		The higher the TSG value, the greater the difference in germination speed between the 'fast' and 'slow' germinating members of a seed lot. Kader (1998)

Table 1. Description of various parameters used to study seed germination.

Day	Seed Lot 1	Seed Lot 2	Seed Lot 3	Seed Lot 4
1	0	95	10	0
2	0	0	20	0
3	0	0	65	15
4	15	0	0	35
5	80	0	0	50
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
Parameters				
FGP (%)	95	95	95	95
MGT (day)	4.8	1.0	2.5	4.1
GI	585	950	800	595
CVG	20.8	100.0	38.7	22.7
GRI (%/day)	19.7	95.0	38.0	23.1
FDG (day)	4	1	1	3
LDG (day	5	1	3	5
TSG (day)	1	0	2	2

Table 2. Seed lots with different germination rates.

Day	Seed Lot 1	Seed Lot 2	Seed Lot 3	Seed Lot 4
1	19	23.7	31.6	47.5
2	19	23.7	31.6	47.5
3	19	23.7	31.6	0
4	19	23.7	0	0
5	19	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
Parameters				
FGP (%)	95	95	95	95
MGT (day)	3	2.4	1.9	1.5
GI	760	805.8	853.2	902.5
CVG	13.3	40.0	50.0	66.6
GRI (%/day)	31.6	39.5	50.0	50.0
FDG (day)	1	1	1	1
LDG (day	5	4	3	2
TSG (day)	4	3	2	1

Table 3. The effect of distribution of seed germination on measurement results.

Day	Seed Lot 1	Seed Lot 2	Seed Lot 3	Seed Lot 4
1	31.6	25	18.3	11.6
2	31.6	25	18.3	11.6
3	31.6	25	18.3	11.6
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
Parameters				
FGP (%)	95	75	55	35
MGT (day)	1.9	1.9	1.9	1.9
GI	853.2	675	494.1	313.2
CVG	50.0	50.0	50.0	50.0
GRI (%/day)	50.0	39.4	28.9	18.4
FDG (day)	1	1	1	1
LDG (day	3	3	3	3
TSG (day)	2	2	2	2

Table 4. Germination percentage variations over a 3-day spread.

Day	Seed Lot 1	Seed Lot 2	Seed Lot 3	Seed Lot 4
1	10	70	10	15
2	15	15	70	70
3	70	10	15	10
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
Parameters				
FGP (%)	95	95	95	95
MGT (day)	2.6	1.3	2.0	1.9
GI	795	915	850	860
CVG	31.6	73.0	48.7	51.3
GRI (%/day)	36.5	73.0	47.5	50
FDG (day)	1	1	1	1
LDG (day	3	3	3	3
TSG (day)	2	2	2	2

Table 5. Germination concentration and its impact on germination rates.

Day	Seed Lot 1	Seed Lot 2	Seed Lot 3	Seed Lot 4
1	13.5	19	31.6	95
2	13.5	19	31.6	0
3	13.5	19	31.6	0
4	13.5	19	0	0
5	13.5	19	0	0
6	13.5	0	0	0
7	13.5	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
Parameters				
FGP (%)	95	95	95	95
MGT (day)	3.9	3.0	1.9	1.0
GI	661.5	760	853.2	950
CVG	25.0	33.3	50.0	100.00
GRI (%/day)	24.3	31.6	50.0	95.0
FDG (day)	1	1	1	1
LDG (day	7	5	3	1
TSG (day)	6	4	2	0

Table 6. Time course of germination impacts on measurement data.

Day	Seed Lot 1	Seed Lot 2	Seed Lot 3	Seed Lot 4
1	0	0	0	0
2	0	0	0	31.6
3	0	0	0	31.6
4	0	0	31.6	31.6
5	0	0	31.6	0
6	0	31.6	31.6	0
7	0	31.6	0	0
8	31.6	31.6	0	0
9	31.6	0	0	0
10	31.6	0	0	0
Parameters				
FGP (%)	95	95	95	95
MGT (day)	8.9	6.9	4.9	2.9
GI	189.6	379.2	568.8	758.4
CVG	11.1	14.2	20.0	33.3
GRI (%/day)	10.6	13.7	19.3	32.7
FDG (day)	8	6	4	2
LDG (day	10	8	6	4
TSG (day)	3	3	3	3

Table 7. Early and late germination spread impacts on germination rate.

Day	Seed Lot 1	Seed Lot 2	Seed Lot 3	Seed Lot 4
1	9.5	18.7	27.5	35
2	9.5	18.7	27.5	0
3	9.5	18.7	0	0
4	9.5	18.7	0	0
5	9.5	0	0	0
6	9.5	0	0	0
7	9.5	0	0	0
8	9.5	0	0	0
9	9.5	0	0	0
10	9.5	0	0	0
Parameters				
FGP (%)	95	75	55	35
MGT (day)	5.5	2.4	1.5	1
GI	495.5	635.8	522.5	350
CVG	18.1	40.0	66.6	100
GRI (%/day)	17.2	31.2	36.6	35
FDG (day)	1	1	1	1
LDG (day	10	4	2	1
TSG (day)	9	3	1	0

Table 8. Percentage and spread of germination effects on measurement parameters.

Day	Seed Lot 1	Seed Lot 2	Seed Lot 3	Seed Lot 4
1	0	31.6	0	80
2	0	31.6	0	10
3	0	31.6	0	5
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	31.6	0	80	0
9	31.6	0	10	0
10	31.6	0	5	0
Parameters				
FGP (%)	95	95	95	95
MGT (day)	8.9	1.9	8.2	1.2
GI	189.6	853.2	265	930
CVG	11.1	50.0	12.1	82.6
GRI (%/day)	10.6	50.0	11.5	79.1
FDG (day)	8	1	8	1
LDG (day	10	3	10	3
TSG (day)	2	2	2	2

Table 9. First day of germination, time spread and percentage germination variations.

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An Apparent Diatreme Source for Gem Corundums and Zircons, Gloucester River, New South Wales

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Abstract: A mineral sample from the AuK2 diatreme site, Gloucester River, NSW, was studied by X-ray diffraction. It contains a gem association (ruby, sapphire, zircon, sapphirine) among minerals from xenolithic (almandine-rich garnet, diopside, spinel) and megacryst (phlogopitic mica, hastingsitic amphibole, rutile) suites and from quartzose components within Carboniferous sedimentary beds. The grain characteristics suggest a proximal source or sources. Fission track dating of zircons gave three separate ages, Palaeocene (62 Ma) for moderate uranium content zircons, Eocene (39 Ma) for low U zircons and Pliocene (4 Ma) for high U zircons. This implies either repeated eruptions among Gloucester River diatremes or incomplete thermal resetting of zircons. The AuK2 sample suggests diatremes play a role as gem sources in the Barrington field.

Keywords: Diatreme, ruby, sapphire, zircon, fission track dating, gemstone sources.

INTRODUCTION

At Barrington Tops, rubies, sapphires and zircons from Cenozoic plateau basalts shed into alluvial placer deposits and formed a commercial gemfield (Sutherland and Graham 2003, Roberts et al. 2004). Mining from placers at Gummi Flats, Upper Manning River, began in March 2005 with plans to market the rubies as faceted, but untreated Australian stones (Cluff Resources Pacific NL 2005, P. Kennewell, pers. com. 2005). The Cenozoic basaltic eruptives here are suspected as the sources for the megacrystic gem material within the placers, as evidenced by marked magmatic corrosion or high temperature fusion crusts on many corundums (Sutherland and Coenraads 1995, Sutherland et al. 1998a, Roberts et al. 2004). No direct examples of corundum and/or zircon in basalt, however, are recorded. This paper provides the first description of these gem minerals associated with an explosive eruptive body, namely the AuK2 breccia pipe, a diatreme located within a tributary of Gloucester River, 25 km WSW of Gloucester township, New South Wales.

Material at AuK2 pipe was sampled during diamond exploration, when it and the nearby AuK1 pipe were tested for diamonds between 1967 and 1971 (MacNevin 1977). Sampling of AuK2 by Stockdale Exploration was observed by A.W. Chubb, a Gloucester resident, council road worker, part-time prospector and a longstanding correspondent with the Australian Museum Mineralogy Department. In a letter to the Department dated '5-1-73' he described '...a 500 acre area we applied for, covering an area Stockdale (DeBeers) relinquished after finding a pipe of granulite and eclogite which contains microscopic diamonds and very nice pale lemon yellow coloured zircon. The largest of the zircon I saw was about as big as the end of my thumb to the first joint, plus plenty more which would be from five to fifteen carat'. He also marked the precise location of the pipe on a Gloucester 1 inch to 1 mile army map for the Museum. This corresponds with the AuK2 site located on Stockdale report maps at Watsons Creek.

In August 1995, after discussion on the AuK pipes with two of the authors (F.L. Sutherland and G.B. Webb), A.W. Chubb provided the Museum with a taped packet of mineral concentrate from AuK2. It is uncertain whether the sample was taken directly from the exposed pipe or from material around the pipe. Recent detailed examination of this sample (G.B. Webb) revealed the presence of gem corundums

and zircons, the significance of which is presented in this paper. The paper is dedicated to Arch Chubb, for his input into the Australian Museum Barrington gemstone research program from 1969 until his death in 1996.

GEOLOGICAL SETTING

The AuK1 (Grid 377700 E, 6451200 N; 360 m asl) and AuK2 (377400 E, 6452200 N; 330 m asl) diatreme pipes lie in adjacent tributary drainages leading into Gloucester River (Dungog 1:100,000 Map Sheet, Zone 56, AGD 1966). The Gloucester River rises some 10 km west of the AuK sites (Figure 1), among remnant basalt cappings and gem-sites on the Late Palaeozoic granodiorite-intruded basement massif exposed on Gloucester Tops at elevations around 1300 m asl (Roberts et al. 1991, Sutherland and Graham 2003). Some confusing differences exist in the drainage nomenclature at the AuK sites, with Watsons Creek and Oaky Creek as designated in the Stockdale exploration reports (MacNevin 1977) being renamed as Oaky Gully and Flaggy Creek respectively in the later Dungog 1:100,000 maps (Roberts et al. 1991).

The pipes intrude dominantly westerly-dipping (approx. 21°–33°) Early Carboniferous metasedimentary beds. The AuK2 site is structurally located near a fault intersection (Figure 1), where Early Carboniferous Conger Formation beds form a wedge against undifferentiated Early Carboniferous beds. Several magnetic anomalies were linked to garnet sources at the AuK sites (Stracke 1971) and with other rock samples suggest multiple diatremes and dykes exist in this area.

The AuK1 and AuK2 pipes both yield megacrysts and xenoliths within their altered ultramafic and basaltic host lithologies (Stracke 1971, Wilkinson, 1974, MacNevin 1977). AuK1 contains serpentinised olivine and brown mica in a chloritic, serpentinitic, calcitic and iron oxide-bearing matrix; heavy mineral concentrates yielded garnets, including pyrope, Cr-bearing diopside, orthopyroxene, clinopyroxene, hornblende and diopside. AuK2 samples yielded phlogopitic mica, orange garnet, hornblende and diopside. High-pressure xenoliths (garnet clinopyroxenites, garnet ± scapolite granulite and rare amphibolite) described by Wilkinson (1974) and Griffin and O'Reilly (1986) mostly came from AuK2, while similar xenoliths described by O'Reilly et al. (1988) and Sutherland and Graham (2003) were largely AuK1 material. These garnet-bearing metamorphic assemblages were fragments from underlying lower crustal to upper mantle lithologies and were mostly nepheline-normative in chemical composition. Their isotopic compositions suggest that they represent original island arc or sea-water altered ocean-ridge basalts that were involved in underplating processes associated with Palaeozoic subduction events. It was further suggested that the amphibole-altered mantle lithologies may generate minor felsic melts that produce magmatic sapphires, which are found on the Barrington plateau (Sutherland et al. 1998b).

Definite ages for the Gloucester River diatremes are not established, although links to Jurassic alkaline melts were postulated on the presence of dark mica in the diatremes and in mica megacryst-bearing alnoite dated at 160 Ma northwest of Gloucester (Sutherland and Graham 2003). Zircon megacrysts in the AuK2 sample, however, provide an opportunity for dating eruptive activity around this site. The AuK2 concentrate is also significant for containing similar corundums (ruby and sapphire) to the Barrington Tops-Gloucester Tops gem corundum suites and so bears on the potential sources for the gem deposits. This AuK2 study provides further detail into the eruptive history of the Barrington volcanic province which extends from at least 60 to 3 Ma (Sutherland and Fanning 2001, Sutherland and Graham 2003, Roberts et al. 2004).
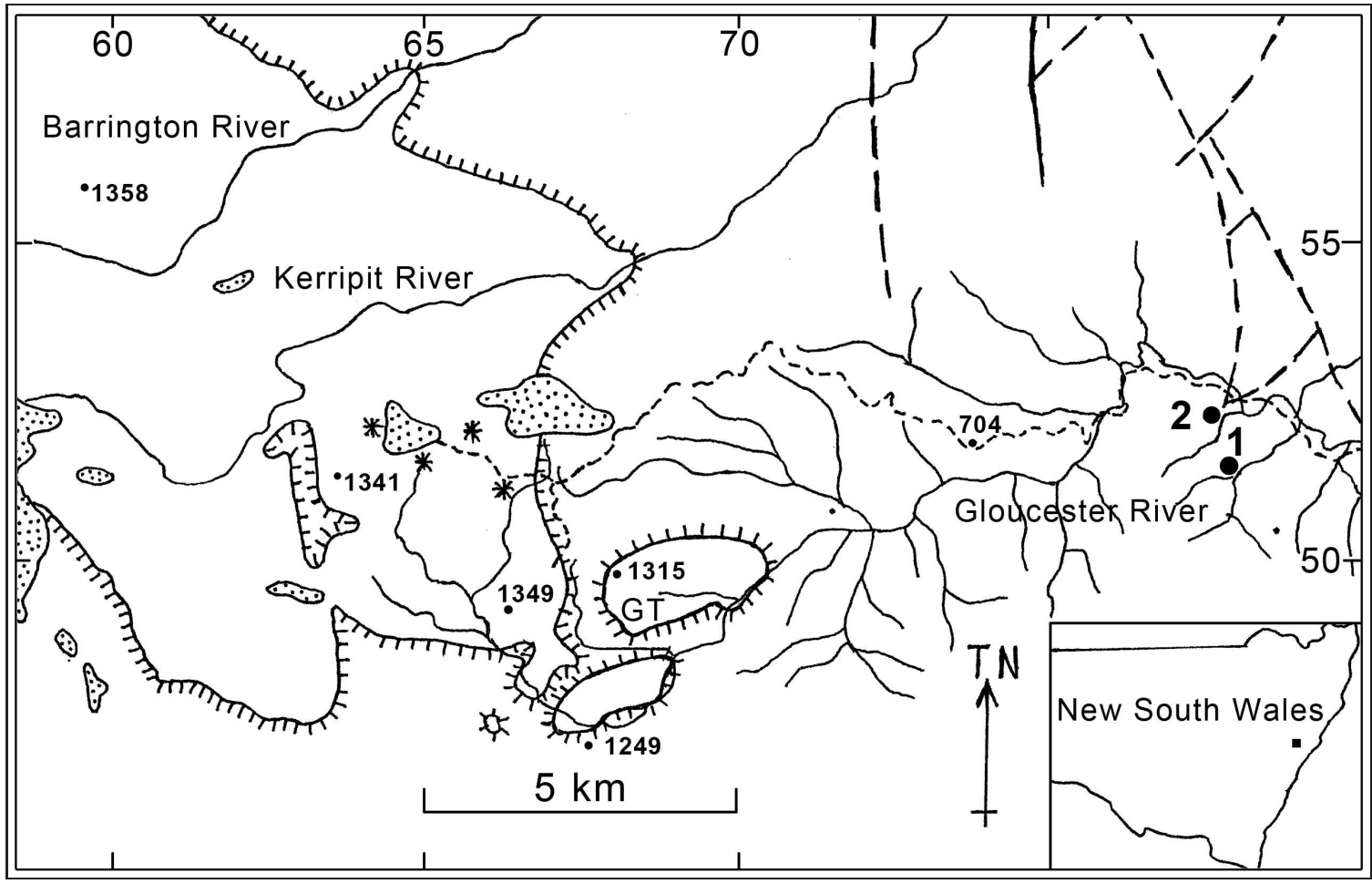
Figure 1. Geological outline map of the Gloucester Tops - Gloucester River area, based on the Dungog 1: 100,000 Sheet mapping (Roberts et al. 1991). Gloucester River (thin drainage lines) is shown along with main drainages for Kerripit River and Barrington River. The Gloucester diatreme sites (solid circles) include AuK1 (1) and AuK2 (2). Geological areas include folded Palaeozoic basement beds (clear areas), contact zones bounding Permian Barrington Tops Granodiorite intrusions (hatchured lines) and Cenozoic basalt cappings (stippled areas). Gloucester Tops gem sites (stars) come from Sutherland and Coenraads (1995). Mapped faults and inferred faults are shown as thick and thick-dashed lines. The Gloucester Tops road from Bucketts Way (short dashed line) follows the Gloucester River before ascending the Gloucester Tops massif. Spot asl elevations in m. The inset (bottom right) shows the map area within New South Wales.

MATERIALS AND METHODS

Mineral grains from the AuK2 concentrate (Australian Museum registration no. D 53724) were examined using a gemmological binocular zoom microscope, ultraviolet light and polariscope and were separated into groups of similar appearance and properties (G.B. Webb). Representative grains from each group were subjected to X-ray diffraction (XRD) analysis. The work mostly utilised a Philips PW 1820 powder diffractometer, mounted on a PW 1825 X-ray generator, operating with $CuK\alpha$ radiation at 40 kV and 30 ma; the patterns were checked against a Traces search and match database (D.M. Colchester). A few minerals were run on similar equipment at the Australian Museum. The mineral groups and identifications are listed in Table 1.

A colour range of zircons chosen from the concentrate was submitted to Geotrack International PL, Melbourne, for fission track analysis. Grains were mounted in Teflon and etched in molten KOH-NaOH (Gleadow et al. 1976). Mounts were sealed in low-uranium mica detectors and placed between uranium standard glass, before insertion into an aluminium can for irradiation. After removal, mounts were etched in hydrofluoric acid and fission tracks were counted using Zeiss® Axioplan microscopes. Fission track ages were calculated after Hurford and Green (1982). The zeta calibration factor was determined (Hurford and Green 1983) and grain ages were calculated using Poissonian statistics (Galbraith 1981, Green 1981). The results, including graphical radial plots, were presented in Geotrack Report #946 (2005) for the Australian Museum (P.F.Green, analyst) and are collated in Table 2.

RESULTS

The mineral grain identifications not only confirmed previously identified megacryst and xenolith species from AuK2 exploration investigations (vermiculite altered from phlogopite 3T?, almandine, hastingsite and diopside), but also identified a range of other minerals. These included corundum (varieties ruby and sapphire) and zircon, typical of Barrington Top plateau gem suites, and sapphirine in independent grains, whereas normally it is found as intergrowths and inclusions in Barrington rubies. The presence of well-developed, and even complete alteration crusts on some ruby and garnet cores suggests there was minimal transport from the source rock.

The zircon fission track results on 20 crystals suggest three age groups of zircons, each with differing U contents (Table 2). The oldest group, with moderate U contents (150–300 ppm) is Palaeocene and at a 62 ± 6 Ma is among the oldest zircons associated with the Barrington shield volcano. An intermediate age group, with low U contents (30–80 ppm) is Eocene and at 39 ± 7 Ma appears to mark a slightly younger eruptive event than found for widespread similar zircons (av. U 72 ppm) on Barrington plateau (44 ± 3 Ma). The youngest Pliocene age group has higher U contents (180–840 ppm) and at 4 ± 1 Ma overlaps a high U group (5 ± 1 Ma) within the Gloucester River catchment on Gloucester Tops (Sutherland and Fanning 2001). The latter zircons, however, are different in colour, crystal shape and transparency and are significantly higher in U (> 1000 ppm) and, have noticeable metamict cracking; such detrital crystals would not survive intact during extended transport down Gloucester River and denote a separate source.

A range of quartzose grains was identified among the in the AuK2 sample. Small, irregular quartz aggregates suggest fragmented quartzitic materials, expected from explosive blasting of metasedimentary beds during diatreme emplacement. Rounded, polished chalcedonic nodules resemble worn transported materials, but could represent originally recycled material in the local sedimentary beds. Angular fragments of crystallised quartz could come from extensive quartz veining within the local beds.

Material	Description	Identification	Abundance
Pale, dark pink, and red grains	Angular to round, flat to equant, up to 1 cm. Some corroded surfaces, fusion crusts, sapphirine (?) intergrowths	Corundum (XRD) ruby (colour)	Common
Grey, yellow and blue grains	Subangular to flattened, up to 0.8 mm, some corroded, some include silk	Corundum (XRD) sapphire (colour)	Common
Purple, mauve and purple-mauve grains	Subangular, up to 0.7 mm	Corundum (XRD) sapphire (colour)	Sparse
White, yellow, orange brown and red grains	Anhedral to subhedral, irregular to prismatic, lustrous, up to 0.6 mm, some corroded or fluorescent in UV light	Zircon (optics) F.T. Analysis	Sporadic
Pink, red grains	Subangular, up to 0.6 mm	Almandine (XRD)	Rare
Green, black grains	Angular, some elongate, up to 0.6 mm	Sapphirine (XRD)	Rare
Brown, black flakes	Flat, cleavage flakes, partly altered	Vermiculite (XRD)	Sporadic
Dark brown crystals	Subangular, elongate, up to 0.5 mm	Hastingsite (XRD)	Sparse
Dark, green grains	Subangular, up to 0.7 mm	Enstatite (XRD)	Sparse
Grey green grains	Irregular, some elongate, up to 0.9 mm	Diopside (XRD)	Sporadic
Black opaque grains	Rounded to irregular, shiny, partly conchoidal, up to 0.5 mm	Spinel (optics)	Sporadic
Black crystal	Tabular, brown coating, up to 0.8 mm	Rutile (XRD)	Rare
Black grains	Shiny, red in part, up to 0.5 mm	Hematite (optics)	Rare
Black grain, red core	Spinel-rich? crust, 3 mm across	Spessartine (XRD)	Rare
Clear to smoky chips	Angular, part conchoidal, up to 0.6 mm	Quartz (optics)	Common
White, grey nodules	Polished, rounded, up to 1 cm	'Chalcedony' (optics)	Common
Red, brown grains	Polished, subangular, up to 0.7 mm	'Jasper' (optics)	Sporadic
Yellow, grey grains	Rounded, with ragged angular edges, up to 0.5 mm	Quartz (XRD)	Sporadic
Pale green masses	Irregular, rounded to elongate, diffuse surface, up to 0.9 mm	Diopside-augite alteration (XRD)	Sparse

Table 1. Mineral groups, separated from AuK2 concentrate sample (D53274). Common (>20 % grains), sporadic (10–20 %), sparse (5–10 %), rare (<5 %).

Grns	Ns(av)	Ni(av)	Na(av)	ρ_s(av)$\times 10^6$	ρ_i(av)$\times 10^6$	Uppm(av)	FT Age$\pm 1\sigma$(av)
Palaeocene (moderate U) group							
4	310	251	100	4.922	3.922	163–283 (187)	61.7 ± 5.6
Eocene (low U) group							
7	58	71	100	0.917	1.128	31–77 (53)	39.3 ± 7.3
Pliocene (high U) group							
9	58	651	100	0.927	10.350	183–824 (484)	4.2 ± 0.6

Table 2. Zircon fission track (FT) results, AuK2 site. ρ_D (Track density from U standard glass) 1.14×10^6 cm^{-2}. N_D (Total tracks counted for determining ρ_D) 1787. Ages calculated using a zeta 87.7 ± 0.8 for U3 glass. Grns, No. of grains. Ns, No. of spontaneous tracks in Na grid squares. Ni, No. of induced tracks in Na grid squares. Na, No. of grid squares counted in each grain. ρ_s Spontaneous track density. ρ_i Induced track density. Analyst: P.F. Green.

DISCUSSION

The AuK2 mineral sample provides a fuller picture of diatreme mineralogy and emplacement ages in the southeastern Barrington volcanic field. The presence of ruby, sapphire and zircon supports the prospect that diatreme and pyroclastic sources are important vehicles for the provision of these gem materials.

The corundum suites in the AuK2 sample include both metamorphic and magmatic types and mark the most eastern gem site located in the Barrington field. The spread in zircon ages, with three separate groups, is a complicating feature. It implies multiple proximal zircon sources here, as the zircon groups differ to those from the headwaters at Gloucester Tops. Alternatively, some zircon groups were not thermally reset in eruptions. Derivation of gem suites from the Gloucester Tops high country is also unlikely given a comment recorded by Arch Chubb that only 'pulverised sapphires of various colours in the surface wash' were found in the adjacent Kerripit River, 10 km downstream from its incision into Gloucester Tops.

The zircon dating from AuK2 material supplements the previous comprehensive zircon and basalt dating on Barrington Tops plateau (Sutherland and Fanning 2001, Sutherland and Graham 2003, Roberts et al. 2004) and reinforces evidence of repeated, extended volcanic activity in this field. The youngest phase of activity (3–5 Ma) is now identified in four well-separated sites across the whole field (East Tomalla Creek, Gummi Flats, Gloucester Tops, Gloucester River). A southerly decreasing age-trend in young (<12 Ma) zircon ± corundum-bearing volcanic sites was proposed from studies extending from Childers-Proston in Queensland to Uralla-Barrington in New South Wales (Sutherland 1993). Based on this well-established young Barrington event at 4 ± 1 Ma and Australian plate motion rates (7 cm/yr) since then, the present potential eruptive source would now underlie the Wollongong-Southern Highlands region below the southern Sydney Basin.

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Tool Culture, the Baldwin Effect and the Evolution of the Human Hand

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Abstract: Human tool culture seems to have influenced the evolution of human hand anatomy. Difficulties in establishing a causal connection centre on the fact that early hominin hand anatomies supportive of tool culture precede the earliest tools in the archaeological record. Various considerations suggest that the archaeological record may be misleading. Earlier tools would not be visible if they were manufactured from wood or plant material, or if they were natural objects subject to only slight modification. Moreover, the first appearance of stone tools in the record may reflect a switch in the location of home bases or butchering sites, and not the commencement of stone tool usage. Acquisition of modern human tool skills is generally via imitation. There is no strong reason to suppose that a small-brained hominin such as *Australopithecus* was incapable of imitation, or that members of this genus could not have been manufacturers of stone tools. It therefore seems likely that anatomical support for strong grasping and pinch grips, even as early as *Australopithecus*, is a specific adaptation to the cultural practice of tool usage, or perhaps to manipulative practices generally. The Baldwin Effect is a useful explanatory model. By substituting culture for individual learning, and thus reducing the costs of learning, we can use the model to predict the observed outcome, namely the genetic incorporation of bodily structures associated with tool usage, while tool usage itself continues to be cultural.

Keywords: Human evolution, tool, hand, Baldwin Effect, culture

INTRODUCTION

The modern human hand appears remarkably well-adapted to tool use and tool making. Compared with our fellow primates, we have for example a long thumb, the muscles of which are well differentiated. We also possess a specific muscle, the *flexor pollicis longus*, which is frequently absent in other primates. This muscle attaches to the forearm, and allows the thumb to flex at its mid-point (Susman 1988). A powerful, flexible, and relatively long thumb is very useful when grasping objects firmly in order to deploy them as tools.

Notice that we are asserting a link between an evolutionary outcome (hand anatomy) and a cultural practice (tool usage). At least two causal relationships can be recognized: that certain hand anatomies provided a base for culture and, conversely, that culture provided an environment that favoured certain hand anatomies.

This paper assumes that evidence can be found to support both causal relationships, but focusses on the second. The influence of culture on bodily structure and function may be one of the distinguishing features of human evolution.

Let us start with some definitions. The term *tool* can be used inclusively to mean any detached object which is employed for a useful end. Following Wynn (1994), I will use the term more narrowly to mean 'a detached object that is controlled by the user to perform work (in the mechanical sense of transferring energy), usually as an extension of the user's anatomy'. Thus, a carpenter's hammer is a tool, but a bird's nest is not. I shall use the term *culture* to refer to: *shared patterns of behaviour which are acquired, within lifetime, from other members of the same species, usually in the context of social relationships between mutually recognized individuals.*

TOOL CULTURE

Modern human tool usage is predominantly cultural, as shown by the social learning needed to acquire even a moderate level of skill. In some species, however, tool usage shows little variation among individuals and populations (Panger 2002), and therefore may be predominantly genetic in origin. In order to assert a causal role for culture, it is necessary to establish that tool usage among early hominins was also cultural. There is no direct evidence for or against this view, but it gains support from the cultural nature of tool usage among our nearest living relatives, common chimpanzees (chimps). A review of the literature reports that all chimp populations subject to long-term study turn out to be tool makers and users, and that each population has its own customary tool kit (McGrew 1998). Work with the directors of the seven most long-term field studies of chimp behaviour identified a number of behaviours which were significantly present in one population, but absent in others, with no apparent ecological or genetic explanation. Most of these cultural behaviours involved tool usage (Whiten et. al. 1999).

It is not clear whether tool culture first developed in the common ancestor of chimps and humans, or developed independently in both lineages after branching speciation. The question is not fundamental because, on the reasonable assumption that both hominin and chimp tool behaviour has always been predominantly cultural, it is likely that tool usage was invented, lost and then re-invented many times over in all three lineages.

EVOLUTIONARY CAUSES

As a classic paper argued (Gould and Lewontin 1979), present utility does not establish evolutionary origin. The role played by hand anatomy in supporting modern human tool usage does not by itself establish that hand anatomy evolved as an adaptation to tool usage. In particular, hand anatomy may be an adaptation to ancestral practices in ancestral environments, providing a fortuitous pre-adaptation which humans then exploited via tool usage.

Pre-adaptation is clearly an important component of the story, as can be seen by considering chimp tool usage. Unlike monkeys, which move around in trees by traversing the tops of branches or by hanging from their tails, apes (including chimps) lack tails, and move around by climbing, or by hand over hand movement (*brachiation*) while hanging from a branch. The hands of apes are adapted to this style of movement by providing a powerful grip, using four fingers pressed firmly against the palm. Chimps are also ground-dwellers as well as tree-dwellers. It seems to be happenstance that, when using or making tools, chimps have been able to exploit this arboreal ape grip for a different function. If this explanation works for chimps, then it presumably works at least to some degree for the earliest hominins. We too must have been ground-dwelling opportunists who took advantage of an anatomy originally adapted to a tree-dwelling environment.

A second point in favour of pre-adaptation is that it seems to be consistent with the archaeological record of early hominins. The earliest known tools date from 2 to 2.5 million years ago (mya). However, remains of *Australopithecus afarensis* dated to 3.2 mya show anatomical features which provide greater support for tool culture than those of modern chimps, for example a longer thumb relative to the fingers than in chimps. In general, Marzke (1997) identifies eight distinctively human features of the hand (see below), of which *Australopithecus afarensis* exhibited three. Perhaps anatomy did precede tool culture, at least amongst early hominins.

Pre-adaptation, however, cannot be the whole story, for there are just too many distinctive features of the modern human hand which too neatly support tool culture. The important question is not whether a particular hand anatomy is capable of supporting stone tool culture, but the degree to which hand anatomy provides 'economical and effective' support (Marzke 1997).

Stone tools can be made by striking or throwing a softer stone against a harder surface. They may also be made by placing a softer stone against a substrate, and then striking with a harder stone. Efficient production, however, is generally by striking a hard hammer stone held in one hand against a softer core held in the other hand, thereby producing flakes from the core (hard-hammer percussion). Efficient use of flakes as cutting instruments is generally by grasping the flake between the thumb and the forefinger, with or without the support of other fingers. In general, use of prehistoric stone tools places similar demands on anatomy as manufacture of the tools (Marzke and Marzke 2000).

Certain grips are favoured by modern humans who have taught themselves hard-hammer percussion, and these grips are in turn supported by the following anatomical features (Marzke 1997).

1. As noted above, humans have a longer thumb relative to the second finger. The thumb is able to control objects of varying sizes and shapes by moving against all four fingers. If the core is held using an ape-like power grip, i.e., without recruiting the thumb, 'the core must be repositioned for each strike either by dropping it and retrieving it in a new orientation or by shifting its position with the hand holding the hammer stone.'

2. Humans have well-developed intrinsic muscles of the thumb (i.e., muscles attached at both ends to bones within the hand). In humans, thumb intrinsic musculature is 39% of total intrinsic hand musculature, compared with 24% in chimps.

3. As noted above, humans have a proportionately large *flexor pollicis longus* muscle. This muscle attaches to the forearm, and is frequently absent in other primates. It controls the joint at the mid-point of the thumb, allowing the thumb pad to be oriented towards the fingers, and the thumb to be braced against pressure by the fingers.

4. Humans have relatively large pads on the tips of the fingers and thumb. These pads are supported by broader tufts on the distal phalanges (the bones forming the top segment of the fingers and thumb). The larger surface area of these pads 'distribute pressure during forceful grasping', for example when grasping a hammer stone.

5. In humans, the third metacarpal head is oriented towards the thumb. The metacarpus is five bones which are joined to each of the four fingers and thumb, and together provide the skeletal substructure for the palm. The head of the third metacarpal bone is attached to the longest finger, and its orientation towards the thumb assists in grasping large objects such as stones for hammering or throwing.

6. In humans, there is marked asymmetry of the second and fifth metacarpal heads, so that the index finger and little finger are oriented towards each other when grasping a large object, once again maximizing the contact between the inner surface of the fingers and the surface of the object.

7. In humans, the joints between the second metacarpal and three bones in the wrist (the trapezium, trapezoid and capitate) are oriented so that the metacarpal can pronate (rotate palm-downwards) during strong pinch grips between the thumb and the side of the index finger.

8. In humans, the pads on the tips of the fingers and thumb are less mobile than the pads on the remaining finger segments. This allows a firm pinch grip using the tips, while nevertheless allowing greater cushioning and a larger sensory area in the rest of the fingers and thumb.

On the basis of the evidence, it is reasonable to conclude that tool culture has been a key selective agent in the evolution of the human hand. This conclusion does not commit us to any of the fallacies identified by Gould

and Lewontin (1979). The object of our interest is not a single trait considered in isolation from the rest of human anatomy, but a series of interconnected traits. The traits are almost certainly not byproducts of a different adaptation, and we have given due weight to the role of pre-adaptation.

EARLIEST HOMININ TOOL USAGE

Having reached this conclusion, we must address the difficulty mentioned above, namely that remains of *Australopithecus afarensis*, dated to 3.2 mya, show anatomical features supportive of tool culture, when the earliest known stone tools date only from 2 to 2.5 mya. Specifically, the following traits were identified (Marzke 1997).

§ A longer thumb relative to the fingers than in chimps.

§ Asymmetry of the second and fifth metacarpal heads, so that the index finger and little finger are oriented towards each other when grasping a large object.

§ The joints between the second metacarpal and bones in the wrist support strong pinch grips between the thumb and the side of the index finger.

In making the reasonable assumption that these traits evolved sometime after hominin separation from the chimp lineage, i.e., that they were not inherited from the last common ancestor, some explanation is required.

Let us review the evidence for early tool usage. This usage probably would have involved wooden and bone implements, in addition to stone, but the earliest available evidence is almost exclusively of stone tools. This evidence takes two forms. First, direct evidence comes from the form of the tools themselves, and associated remains such as the cores from which they were flaked. Secondly, indirect evidence is provided by microwear analysis of cut marks on animal bones thought to form the remains of hominin meals. Both point to 2 to 2.5 mya as the earliest known date for stone tools (Panger 2002).

Several possible explanations can be suggested for the absence of earlier evidence. If tools were made of other materials such as wood or plant fibre, they would leave little evidence, either directly in the form of tool remains, or indirectly in the form of cut marks. In addition, 'found tools' may have been employed, only slightly modified for the purpose, in the manner of modern chimps. In that case, tool remains may be present but unrecognizable in the archaeological record. It has been suggested that *Australopithecus* discovered the food content of the underground storage organs of plants, such as tubers and rhizomes (Wrangham 2001). Amongst tool-using populations, we can imagine that pieces of wood may have been abraded against a hard substrate, and then used as digging-sticks grasped firmly with the assistance of a relatively long thumb. Such practices would leave little or no evidence in the archaeological record.

Another possibility is that hominins did manufacture stone tools prior to 2.5 mya. It has been argued that the earliest known tools are too sophisticated to be the first examples of their type, as they exhibit evidence of multiple flakes from a single core, some flakes have been re-touched, and the raw material for their manufacture has been transported throughout the landscape (Panger 2002).

It has also been argued that the earliest stone tool usage may be hidden in the archeological record for ecological reasons. Most evidence of stone tools has been gathered from sites containing hundreds or even thousands of stone artifacts. Whether interpreted as home bases, butchering sites, or workshops for making tools, these sites represent a geographic concentration over a relatively short time period. Factors influencing the location of such sites would have included protection from bad weather and the availability of shade. One population living in a savanna environment might have located them under shade trees, while a second population living in a more arid environment might have located them under rock outcrops. Because rock outcrops have a much longer potential lifespan than trees, they will support a greater concen-

tration of stone tools and meal remains over time. Perhaps the emergence of manufactured stone tools in the archaeological record merely marks the first time such tools became archaeologically visible (Brooks and Laden, cited in Panger 2002). This suggestion gains plausibility from the fact that Africa's environment was becoming more arid in the relevant time period, driven by a new ice age.

It may be argued that *Australopithecus* had a relatively small brain, and was therefore not smart enough to have been a manufacturer and user of stone tools. This makes some assumptions about the cognitive capacities required, which can be tested against modern evidence. Studies of tool use in the modern era indicate that two styles of cognition dominate. The first style dominates in the acquisition of skills, the second in the application of those skills to solving problems. Overwhelmingly, tool skills are learned by repetitive showing and doing, rather than desk-based learning, with apprenticeship as the classical form of relationship between teacher and novice. Although the apprentice may later be able to place tasks in a hierarchy of routines and sub-routines, the tasks are initially learned in sequential fashion (first job 1, then job 2, then job 3 ... then finish). The task sequences are committed to motor memory by repetition, using temporal or spatial contiguity to cue the next action in the sequence. It is a cognitive style 'commonly encountered in any human behaviour requiring precise motor coordination. Instrumental musicians, for example, use much the same technique in learning complex passages of music. It is also the essence of most sport' (Wynn 1994). In addition, it is close to the cognitive style which characterizes chimp tool behaviour, although for chimps the phrase 'observing and doing' is more appropriate than 'showing and doing'. Subject to this qualification, the difference between humans and chimps is quantitative rather than qualitative.

If the cognitive processes required to learn tool skills are simple, this is not necessarily true of the cognitive processes involved in actually using the tools, i.e., in adjusting tool behaviour to the specific challenges presented by individual circumstances. Wynn (1994) argues that in this respect modern human tool usage can be an altogether more complex process, involving a sort of 'dialogue' between known sequences (sitting in motor memory) and plans for the task at hand. This will usually involve contingency planning i.e. imagining possible problems, and conceiving possible solutions, before attempting the task. It should be contrasted with the mainly trial-and-error method employed by chimps, and almost certainly early hominins.

The problem-solving skills of modern humans do not appear to be specifically related to tool culture, but represent the application of a generalized intelligence which appears to have evolved for other reasons, possibly connected with group social complexity (Dunbar 1994). If repetitive showing and doing (or observing and doing) is the essential element in tool culture, it seems reasonable to conclude that a small-brained animal could have developed some form of stone tool manufacture and use. Recent discoveries in Flores indicate as much, regardless of whether we regard *Homo floresiensis* as an offshoot from the *Homo erectus* lineage, or as more directly linked to *Australopithecus*.

In conclusion, a range of explanations is possible. At one extreme is the possibility that tool usage among the earliest hominins was no more sophisticated than the tool usage which is plausibly ascribed to our chimp-like ancestor (because we observe it among modern chimps, whose ecology appears to be largely unchanged). At the other extreme, it is possible that tool usage was at a level of complexity somewhere between chimps and the earliest hominin tool culture for which there is archaeological evidence. At the latter extreme, it is not difficult to understand why the hands of *Australopithecus* show some anatomical features supportive of tool culture. At the former extreme, if *Australopithecus* tool culture and modern chimp tool culture are very similar, we must ask ourselves why *Australopithecus* hand anatomies provide some support for tool culture, but those of modern chimps do not.

Let us be clear that chimp hand evolution is not entirely unaffected by chimp manipulative behaviour. In typically thorough fashion, Marzke (1997) has identified features which provide some support for precision grips, but it remains true that the chimp hand is not as well adapted for manipulation. The most likely reason is that the hands of chimps are required to perform multiple functions, and are therefore subject to strongly conflicting selection pressures. Chimp hands are used to support three functions, arboreal climbing and swinging, manipulative activities such as food handling and tool usage, and terrestrial knuckle-walking (chimps use the backs of their fingers to support themselves while travelling on the ground). Hominins, by contrast, had already adopted a bipedal posture by the time of *Australopithecus*. There is a venerable argument that walking on two legs 'frees the hands' for manual activities. This argument has in the past been used to support what we can now see is a mistaken notion, that bipedal locomotion is necessarily associated with tool usage. If re-phrased, however, it does seem to have an element of truth. Perhaps the semi-arboreal existence of *Australopithecus* resulted in a hand more fully open to the selective pressures of manipulation and tool usage, by removing knuckle-walking as a competing pressure, and reducing the pressure in favour of arboreal climbing. If this semi-arboreal existence was sufficient to produce an evolutionary novelty, namely bipedal locomotion, then why not a shift in hand anatomy?

It is also possible that tool culture was insignificant prior to 2–2.5 mya. *Australopithecus* hand anatomy may be an adaptation to manipulative practices generally, and may therefore provide a pre-adaptation to tool usage exploited by subsequent species in the hominin lineage. For example, practices such as breaking nuts or smashing bones for marrow may account for the anatomical features in question (Marzke 1998). However such practices are likely to have been as cultural as tool usage. Perhaps our subject should be manipulative culture more broadly rather than tool culture specifically, but this would not alter the central thesis of this paper, namely that culture has been a selective agent in human evolution.

AN EVOLUTIONARY MECHANISM

If tool culture has been a key selective agent in the evolution of the human hand, by what mechanism did natural selection occur? A useful model is the Baldwin Effect, which may be explained as follows. Imagine a species whose members must individually learn a certain task in order to survive in their environment. Individual learning has costs. It may be dangerous not to perform the task to a high standard immediately (e.g., flight for birds), learning may be distracting and so make predation more likely, and it consumes time and energy which would otherwise be available for other essential tasks such as looking for food. Over generations, individuals with some genetic predisposition for the task are likely to enjoy greater reproductive success. Eventually, genetic predisposition becomes full genetic assimilation, so that what originally had to be individually learned from scratch becomes part of the genetic endowment of the species. This may apply both to behaviour, i.e., the task performance itself, and any bodily processes and structures associated with the behaviour.

Now imagine that the task is cultural in origin, for example being learned by imitating others, rather than individually from scratch. Imitation consumes less time and effort, and reduces the costs of learning. It is in this respect a form of free-loading. The Baldwin Effect can still be expected to operate, but it is now more likely to work on the bodily processes and structures associated with the behaviour, rather than the behaviour itself. Over evolutionary time, humans have become more efficient absorbers and practitioners of tool culture, because our hands (and no doubt other parts of our bodies, including our brains) have evolved to provide more efficient support for the behaviour involved. The behaviour itself, however, has remained cultural.

The Baldwin Effect presupposes that individual organisms must learn a task in order to survive, i.e., it assumes a significant degree of compulsion. Before flight became instinctive, immature birds had to learn to fly because adult member of their species had adopted flight as a 'way of life'. Applying the Baldwin Effect to tool culture also assumes a significant degree of compulsion. There is no direct evidence that tool culture was a compulsory 'way of life' for early hominins, but we can reason backwards from contemporary human culture.

Cultures define the methods to be used in subsistence tasks, but social relationships enforce the use of those methods. Enforcement can work in different ways, sometimes by the explicit use of force, but more often by implicit assumption. Let us imagine a band of scavengers of the genus *Homo*, which happens upon a recent kill. The band might quickly organize itself to ward off competing scavengers, and to remove as much flesh as possible from the carcass before the return of the predator responsible for the kill. These tasks might have been at least partly accomplished with the help of stone cutting tools to remove flesh, as well as weapons, which for this purpose can be considered tools because they are used forcefully to transfer energy (e.g., wooden clubs or spears to ward off other scavengers).

In our imaginary scenario, the enforcement of technique is largely implicit. The group habitually has tools and weapons with it, in the expectation of using them. It is passing through this location at least in part in expectation of finding a fresh kill. Its adaptation to its environment requires group members to be proficient with tools, alternative approaches being effectively ruled out. Some individuals may be more proficient at consuming flesh rapidly at the site of the kill, like the competing scavengers, but we can imagine that explicit group prohibition prevents them. Our imaginary scenario of enforced tool usage specifically mentions the *Homo* genus. While some have contrasted *Homo* as an 'obligate' tool user with *Australopithecus* as merely a 'facultative' tool

user (Tobias 1994), it is difficult to assess the validity of such distinctions. It may be that hominin tool culture developed very gradually and unevenly, out of step with the relatively sudden branching speciations which seem to have occurred in the hominin lineage.

CONCLUSION

Pre-adaptation plays a major role in any evolutionary explanation of human hand anatomy. We have inherited five digits from our vertebrate ancestry. The basic configuration of the five digits, and the fact that they terminate in nails rather than claws, derives from a more immediate arboreal ape ancestor. Anatomical support for strong grasping and pinch-grips, however, seems to have occurred in the hominin lineage alone, and to be a specific adaptation to the cultural practice of tool usage. The Baldwin Effect is a useful explanatory model. By substituting culture for individual learning, and thus reducing the costs of learning, we can use the model to predict the observed outcome, namely the genetic incorporation of bodily structures associated with tool usage, while tool usage itself continues to be cultural.

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Biocosmology: a New Science of the Big Picture

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Summary of a Lecture to the Royal Society of New South Wales
University of Sydney, 4th May 2005.

Abstract: Abstract: It is argued that a cross-disciplinary approach is required if we want to understand how life forms evolved from non-life forms. The new science of cosmobiology is described as a big picture form of astrobiology and an explanation given of how its focus on the expansion and the chemical evolution of the Universe can give us the broadest context for understanding other life that may exist in the Universe.

Keywords: Cosmobiology, astrobiology, evolution, life.

The opposability of your thumb clasping this paper testifies to your arboreal past. Your thumb is made of water, protein and bone, testifying to your status as a terrestrial life form. Water protein and bone are made of hydrogen, oxygen, carbon, nitrogen and calcium, which are in turn made up of protons, neutrons and electrons. Thus, to understand how your thumb came to be, we need to know how sub-atomic particles came together to form atoms, how atoms came together to form molecules, how molecules evolved into life forms and how life forms evolved into creatures that climbed trees and grasped things. We need to know at least the basics of physics, astronomy, chemistry, biology and evolution. No one of these sciences can give us a satisfying picture of the origin and evolution of thumbs, for a thumb (just like every other part of the Universe) has a 14 billion year history and contains no boundaries where its physics ends and its chemistry begins, or where its chemistry ends and its biology begins.

Despite this natural undividedness of all parts of the Universe, universities are partitioned into physics, chemistry and biology departments full of specialists. This intellectual balkanization has a price. It encourages the separation of the Universe into living things studied by biological scientists and non-living things studied by physical scientists. It fosters the pretense that there is a sharp division between the two that should not be crossed. This assumed division thwarts the understanding of the many fundamental connections that exist between the living and the non-living parts of the Universe and it undermines our ability to understand the origin of life and the important transition from non-living to living things.

It is beginning to be recognized that to address the issue of the origin of life and whether we are alone in the Universe, the strong traditional boundary between the life sciences and physical sciences will have to come down. As it does, astrobiologists enthusiastically clamor over the fallen walls — erstwhile reductionistic researchers embracing a more synthetic approach. Astrobiology is a synthesis of astronomy and biology. An even broader and more synthetic approach to the study of the origin of life in the Universe is a combination of cosmology and biology: biocosmology. I believe biocosmology will give us many important insights as we struggle to produce a big picture understanding of how we (and our thumbs) came to exist in the Universe.

Biocosmology focuses on the cosmic evolution of the Universe on the largest spatial and temporal scales. It is a science that studies how the evolution of non-living things created the ingredients and the conditions for the emergence of life. As astronomers study the details of star formation, cosmologists put star formation in context by studying the evolution of star formation since the Big Bang. Biocosmology tries

to identify the cosmic processes which over time have allowed biological creatures like ourselves to come into existence. One such cosmic process is the expansion and cooling of the Universe, as plotted in Figure 1.

Life as we know it is based on molecules; clumps of atoms that froze out of the cooling Universe when its temperature of the universe fell below molecular binding energies (Figure 1). Thus, the expansion and cooling of the Universe has been the most basic prerequisite for the origin of molecules and molecular life. However, life cannot be made out of the cooling hydrogen and helium produced in the Big Bang. Many generations of massive stars had to form and die before the ashes of nuclear fusion accumulated to contain enough oxygen, carbon, nitrogen, sulfur and phosphorus to produce watery environments and allow the chemical evolution of carbon molecules into hydrocarbons, carbohydrates and life.

Four elements make up more than 99% of the atoms in terrestrial life: hydrogen, oxygen, carbon and nitrogen. Add seven more elements to this mix (S, P, Cl, Na, Mg, K and Ca) and we have more than 99.99% of the atoms in terrestrial life. Of all these ingredients, only hydrogen was made in the Big Bang; the rest were produced in the hot fusing cauldrons of massive stars all over the Universe. Their ubiquity ensures that the ingredients for life are present throughout the Cosmos.

Water is one of the most essential ingredients for life and is one of the most abundant molecules in the universe. In fact, water is the most common triatomic molecule in the Universe. This makes sense since hydrogen is by far the most common element in the Universe and, after the inert noble gas helium, oxygen comes next in abundance. To be useful to life, H_2O must be a liquid, not ice or steam. To remain a liquid on the surface of a terrestrial planet, the planet should be orbiting a star in the circumstellar habitable zone.

There are many reasons to believe that terrestrial planets, broadly defined, in habitable zones are ubiquitous in the Universe (Lineweaver et al. 2003). For example, planets are formed in accretion disks and accretion disks are necessary ingredients in our best models of star formation. The latest observations and simulations are consistent with the possibility that rocky planets orbit the majority of stars.

Even if we accept that terrestrial planets are common, in order for life to emerge and evolve into something interesting, millions or even billions of years in a clement stable aqueous environment may be required. Supernovae are the required suppliers of O, C, N, S and P but if they explode nearby they can also extinguish life. Thus, there may be a Galactic Habitable Zone close enough to the debris of supernovae to enjoy a complex chemistry but far enough away from supernovae to enjoy a clement environment for the perhaps billions of years required for the biological evolution of interesting organisms (Lineweaver et al. 2004).

From the aqueous environment sketched in Figure 2, life emerged on Earth about 4 billion years ago and branched into the three domains shown at the top of Figure 2 and in Figure 3: *Eubacteria*, *Archaea* and *Eukarya*. We have many ideas about how life got started but none of them are compelling or complete. However, recent progress in molecular biology and genetics has allowed us to trace out the evolutionary tree of life on Earth, showing how all life forms are related to each other (Figure 3).

We do not know if such a tree of life exists on other terrestrial planets. However, we can use this tree to make better guesses about what forms of life we should expect elsewhere. For example, life forms at the root of this tree are the common ancestors of all life on Earth. They are simpler and less quirky than the life forms they evolved into and these simpler organisms therefore may be more representative of what we should expect to find at the base of alien trees of life. That is to say, as far as predicting aliens goes, the smart money is on hyperthermophilic bacteria, not vertebrates.
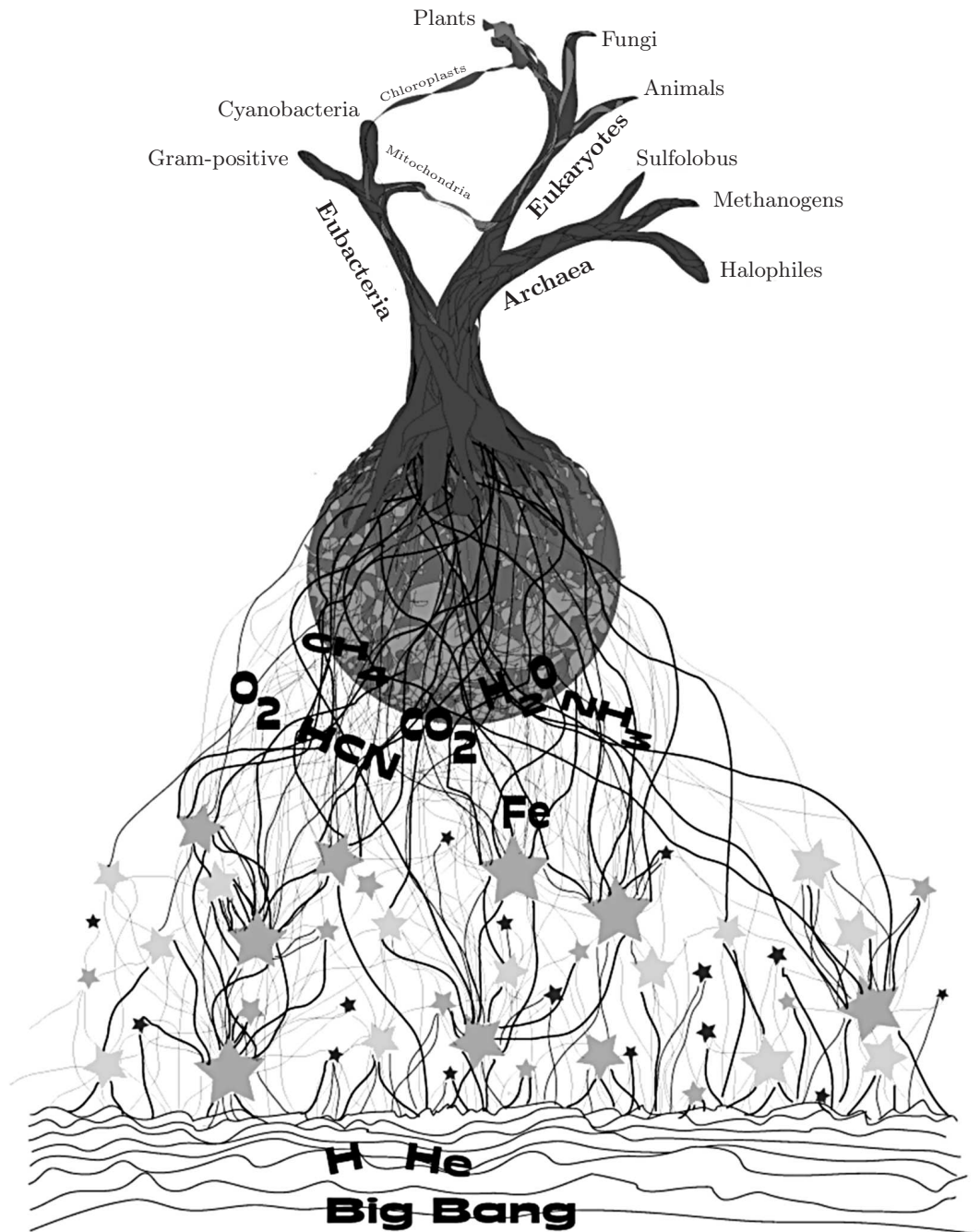
Figure 1. The most important thing one needs to know about cosmology is that the Universe used to be very hot and has been cooling down since its beginning. The sloping line labeled CMB is the temperature of the Cosmic Microwave Background, which is the temperature of the Universe. The molecules, atoms and subatomic particles that we now take for granted have not always existed. As the hot Big Bang cooled, matter came into existence probably about 10^{-33} seconds after the Big Bang. At a thousandth of a second after the Big Bang the quark-gluon plasma cooled and condensed into protons and neutrons. Within three minutes these particles had condensed into light nuclei. As the Universe continued to cool, atoms formed for the first time and as the atoms cooled below the binding energy of molecules, molecules were able to form. If the Big Bang had produced oxygen, water would have been able to form then, but water had to wait until stars formed and produced oxygen (see Lineweaver and Schwartzman 2004 for details).

Figure 2. The history of the Universe since the big bang is summarized in this cartoon. The hot Big Bang (bottom) produced hydrogen and helium (H and He). Clouds of H and He gravitationally collapsed to form stars of various masses. The massive stars exploded after a few million years and spewed into interstellar space the ashes from the nuclei that had fused in their cores. After eight billion years of such reprocessing and accumulation, our Sun formed five billion years ago from a gravitationally collapsing cloud of molecular hydrogen contaminated by oxygen, carbon, nitrogen and other heavy elements. The Earth formed from this contamination in the accretion disk around the young Sun. As the Earth accreted, water was deposited on its surface by comets and water vapour outgassed from hot rocks, just as volcanoes do today.
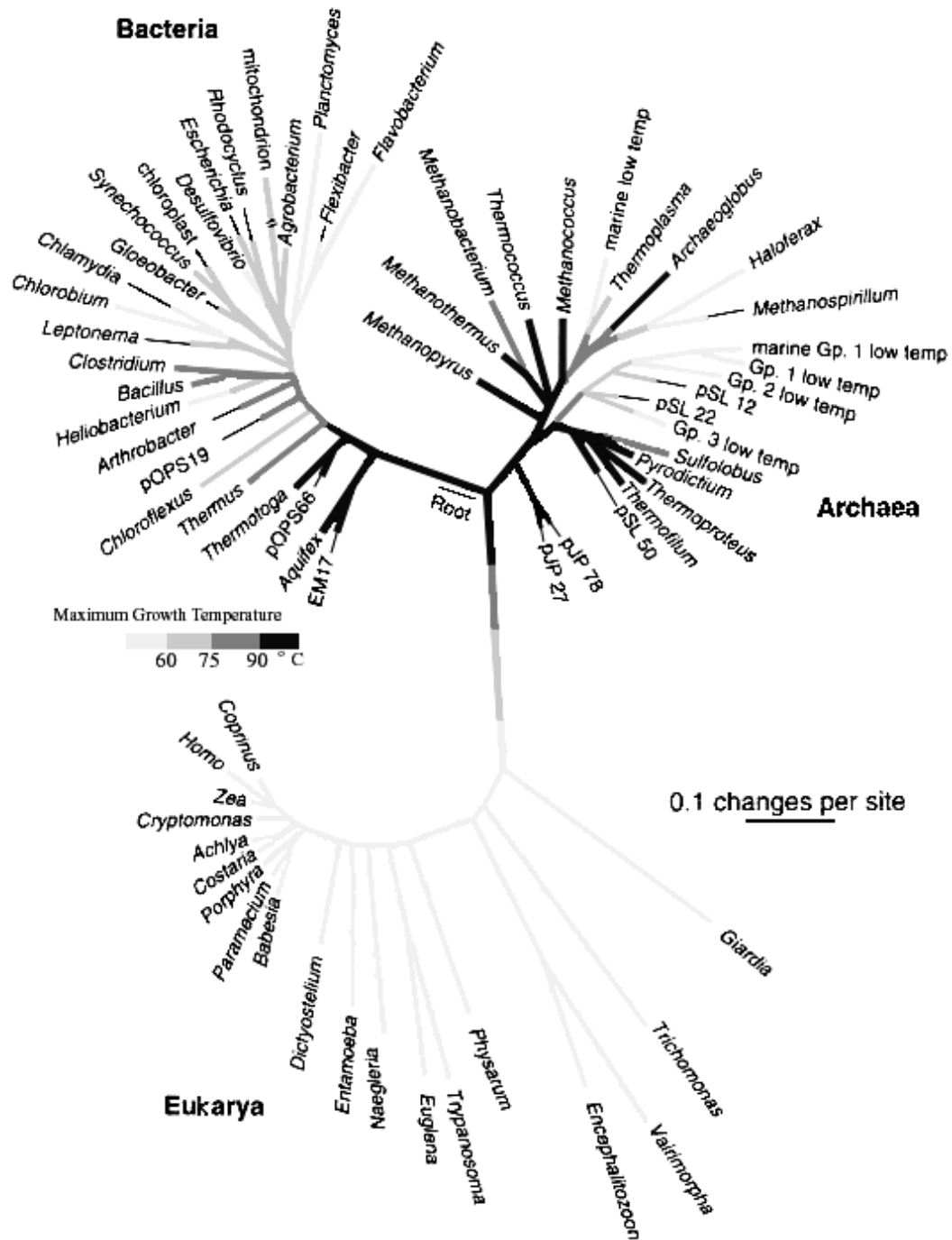
Figure 3. Phylogenetic tree of life on Earth based on 16S rRNA sequences. Life started as a hyperthermophilic *eubacteria* or *Archaea* and branched out (see Lineweaver and Schwartzman 2004 for details). Maximal growth temperatures have been used to assign a grey scale to the branches and thus to construct this biological thermometer on billion year time scales (see Pace 1997 for details concerning the construction of this tree).

Consider the two biocosmological facts (1) terrestrial biogenesis occurred rapidly and life formed on Earth soon after it was able to, and (2) terrestrial planets are not made of anything unique; life forms and planet Earth are made of the most common elements available in the Universe. These facts suggest that life may be common on terrestrial planets throughout the Universe (see Lineweaver & Davis 2002 for details).

Combining our knowledge of the cooling of the Universe and of the formation of stars and planets, and of the composition of those planets and the earliest forms of life on Earth is one example of how biocosmology brings together the study of life forms and cosmic processes to help us understand how we fit into the Universe and how we compare to other life forms that may inhabit the Universe.

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Thesis Abstract: Pulse Transit Time as a Tool in the Diagnosis of Paediatric Sleep-Related Breathing Disorders

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Abstract of a Thesis submitted for Doctor of Philosophy
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Sleep related breathing disorders in childhood are increasingly recognised as contributors to morbidity as well as suboptimal physical, mental and social development. The associated cost in social and economic terms is clearly significant. Detection and diagnosis of such disorders can be costly and technically difficult. Multi-parameter monitoring like polysomnography is expensive and inappropriate for mass screening or investigations remote from tertiary centres.

A simple and non-invasive cardiovascular approach termed pulse transit time (PTT) is useful in determining the status of upper airways during sleep. This approach employs the measurement of the time delay in the arterial pulse pressure wave from the aortic valve of the heart to a peripheral site. PTT has shown promise to provide quantify inspiratory effort in adults with sleep disordered breathing (SDB) and can then be an effective monitoring tool in children. Initial investigations explore the parameters that can confound the PTT measurements of a child. This work provides an estimate of the expected PTT ranges from infancy to childhood. Thereafter, overnight PTT recordings were performed in conjunction with PSG studies to corroborate evidence for its capability in paediatric respiratory studies. The results show that PTT has the ability to identify abnormal respiratory events during sleep. Furthermore, the use of PTT can differentiate the nature of respiratory events as obstructive or central. Technological considerations to improve the robustness of PTT measure to be used not only in cardiorespiratory but also cardiovascular studies on children were also illustrated. Preliminary findings obtained here suggest that the properties of PTT show promise as a predictor for obstructive sleep apnoea. There is a need to bridge the gap of providing quality SDB diagnosis and yet accommodating requirements for a robust screening measure. PTT has demonstrated its suitability and utility as a measure to play a role in the investigation and monitoring of treatment in this area.

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Thesis Abstract: Characterisation of Blood Dendritic Cells in Patients with Cancer

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Dendritic cells (DC) are the key antigen-presenting cells (APC). They play a critical role in initiating specific cellular and humoral immune responses and have been implicated in the defective function of the immune system during cancer progression. Despite the well-demonstrated role of DC in modulating anti-tumour immunity, only a few studies have investigated the systemic effect of cancer on *in vivo* circulating DC populations. In the present study, the effects of cancer on the immune system were assessed focusing on how it affects the function of different populations encompassed within the blood DC compartment. The study of the function of cells within the blood DC compartment (as opposed to *in vitro* generated DC) was chosen despite the fact that it implies significant technical constraints, because they represent the *bona fide* DC populations. Moreover, blood DC are in their natural state of differentiation and free from the influence of exogenous cytokines thus, reflecting more directly the natural biology of systemic immune responses occurring *in vivo*.

Given that tumours have been demonstrated to produce a plethora of immunosuppressive factors that exert systemic effects on immune cell function affecting DC, the first stage of this research aimed at reviewing current evidence on the effects of tumours on DC biology. Reports describing the role of tumour-derived factors in the induction of DC dysfunction are examined and discussed in view of the current knowledge to suggest that tumour-induced alteration of DC differentiation, maturation and longevity is one of the crucial mechanisms for tumour-induced immune suppression in cancer.

Therefore, the next stage of the research program investigates the effects of tumours on the frequency and phenotype of circulating DC. To evaluate this, blood DC counts, phenotype and subset distribution were monitored in a cohort of patients with early (Stage I/II, n=95) and advanced (Stage III/IV, n=21) breast cancer showing evidence that the blood DC compartment can be compromised by disease progression. Blood DC numbers were consistently reduced in patients with advanced disease suggesting a diminished availability of DC precursors in patients with more systemic disease. Moreover, a prolonged period of reduced DC counts extending over 48 weeks after tumor resection was documented in patients with early disease. Finally, the blood DC compartment in patients with advanced disease revealed an alteration in (i) the distribution of myeloid (CD11c$^+$DC) and plasmacytoid (CD123^{hi}DC) subtypes as well as (ii) reduced expression of molecules essential for optimal co-stimulation and antigen presentation to T-cells.

The next stage of research further explores the nature of these alterations. It is demonstrated that the reduction in myeloid and plasmacytoid DC counts is associated with the accumulation of a previously undefined population of HLA-DR$^+$CD11c$^-$CD123$^-$ cells lacking markers for most mature hematopoietic lineages (HLA-DR$^+$ immature cells, DR$^+$IC) in a cohort of patients with breast (n=120) and prostate (n=10) cancer as well as malignant glioma (n=6). In order to study their functional phenotype, DR$^+$IC from cancer patients were purified and side-by-side comparisons were performed with their DC counterparts.

Light and electron microscopy revealed that DR$^+$IC are small cells with poorly developed organelles and condensed chromatin in the nucleus, suggesting immaturity. Phenotypic characterisation showed heterogeneity with variable expression of antigens ascribed to the DC, early B-cell and progenitor lineages. Moreover, in contrast to DC, DR$^+$IC exhibit limited capac-

ity to capture antigen eliciting reduced proliferation and IFN-γ secretion by allo-reactive T-cells. Finally, increased numbers of these cells correlate with disease status and tumour progression. This is exemplified by the fact that patients with advanced breast cancer demonstrate a significantly larger number of DR$^+$IC in the circulation than patients with early disease, and also, the observation that in patients with fully-resected malignant glioma, the proportion of DR$^+$IC in blood is increased when clinical evaluation indicates tumour progression.

The fourth phase of this study evaluates whether DR$^+$IC could have an impact on the nature of the immune response. For this purpose, DR$^+$IC and DC were co-purified and their function thoroughly assessed including capacity to capture and present antigens as well as the nature of the T-cell responses generated. In contrast to DC, DR$^+$IC exhibited a limited response to inflammatory cytokines (TNF-α IL-1β, IL-6 and PGE$_2$) or ligands for toll-like receptor (TLR) 4 (Lypopolysaccharide, LPS), TLR3 (viral double-stranded RNA, poly I:C) and TLR9 (bacterial DNA, CpG oligodeoxynucleotide; CpG ODN) in terms of phenotypic maturation (CD40, CD80, CD83, CD86 and HLA-DR) or cytokine secretion (TNF-α IL-10 and IL-12). In addition, in all the systems tested (antigen uptake, allogeneic T-cell proliferation, CTL-elicitation, MHC-II-restricted antigen presentation and cross-presentation), DR$^+$IC were significantly less efficient than DC. DR$^+$IC induced poor Th1 (IFN-γ, TNF-α and IL-2) and preferentially induced Th2 bias (IL-4) in activated T-cells. Interestingly, DR$^+$IC exhibited marked resistance to the pro-apoptotic effect of tumour-derived supernatants and exhibited substantial migratory capacity to inflammatory cytokines *in vitro*. Finally, ways to differentiate and optimize the function of DR$^+$IC as antigen presenting cells were investigated. It was found that despite the poor responsiveness to inflammatory or pathogen-derived factors, CD40 stimulation induced phenotypic maturation and secretion of bio-active IL-12, in turn, generating more efficient T-cell activation.

Finally, the implications of the aforementioned findings in relation to tumour-induced immune suppression, DC-based immune monitoring as well as DC-based immunotherapeutic strategies for cancer are discussed. The relevant data are presented to support the notion that disease progression in cancer patients can have significant effects on the blood DC compartment. Indeed, the evidence gathered here indicate that immature cells (DR$^+$IC) that accumulate in patients with cancer can contribute to immune suppression by means of inefficient antigen presentation, displacement of DC populations and/or generation of inadequate immune responses. It is also suggested that given the remarkable differences in functional capacity and responsiveness between DR$^+$IC and DC, the evaluation of blood DC broadly defined as Lin$^-$HLA-DR$^+$ cells is to be carefully assessed, particularly in patients with cancer, where DR$^+$IC represent a significant proportion of this compartment. More importantly, this study identifies an approach (CD40 stimulation) able to activate and differentiate these cells *in vitro*, thus generating more efficient T-cell responses. The finding that CD40 ligation not only boosts the antigen-presenting cell function of DC but also DR$^+$IC, substantiates the utilization of ex vivo conditioned APC to correct the unbalanced immunologic performance in cancer and may prove to be crucial in improving the efficacy of DC-based immunotherapies for cancer.

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Biographical Memoir

Hugo Messerle
1925 – 2002

Professor Hugo K. Messerle FTSE,
BEE (Hons), MEngSc, PhD, DSc.

Prof. Hugo Messerle died on September 16, 2004, after some years of declining health. He had a remarkable life story.

Hugo Messerle was born in Palestine in 1925, his parents being members of the small religious group called "The Temple Society". "The Temple Society", led by Pastor Hoffmann, was a group that broke away from the State Evangelical Lutheran Church of Stuttgart in Germany, in the 1850's. Other members of this society migrated to Russia and also to USA. Hugo's father, a cabinet maker, was born in the Caucasus's in Russia of this group. The Templers group in Palestine, (unconnected with the Knights Templars of the Crusades) maintained their own German language, schools, culture and traditions, but nevertheless had good relations with the surrounding Arab and Jewish population. After the first world war, Palestine became a Mandate of the British government. In 1941, after the outbreak of the second world war, the British became concerned, with the advance of Rommel in North Africa, that this large German group would undermine the security of Palestine for the British. The German settlements were then surrounded by armed guards and became internment camps. Furthermore over 600 Templers, together with other Germans, were deported from Palestine on the large British boat, the QE I. Hugo and his parents were put on this boat, not knowing where they were going. It was only after their departure that they found out that they were destined for Australia, where they were interned for 5 years at Tatura, a small town in northern Victoria.

The Templers were treated very well by the Australian guards, despite many in these internment camps expressing understandable sympathy for the German cause. Classes were organised for the children in the camps, and Hugo did these courses and a full examination for university matriculation. However, these courses were nearly all in German, and were designed for matriculation at German universities, facilitated through Berlin by the Red Cross. After the war was over and the treatment of the Jewish population within Germany became public knowledge, there were very strong anti-german feelings particularly from the Jewish population within Palestine. As a consequence the Templer community remaining within Palestine, became untenable as a coherent German group and there was little possibility of the Templers in Australia returning to Palestine. However, the new German government validated the matriculation exam that had been passed by Hugo and three others in the internment camp. Fur-

thermore, after significant difficulties, the University of Melbourne also accepted these exams as matriculation for Melbourne university, and Hugo was able to enrol and study at the University of Melbourne. He graduated with first class honours in Electrical Engineering and also obtained a Masters in Engineering Science and a Doctor of Science degree from the University of Melbourne and a PhD degree from the University of Sydney.

It is remarkable that from such beginnings, as an internee confined for 5 years for the protection of Australian society, Hugo went on to become a leading Australian academic, a research scientist with an international reputation, and was head of the Department of Electrical Engineering at the University of Sydney for almost 20 Years. This career has three components, his many research publications, his influence as head of a university department, and his research contribution in the field of Magnetohydrodynamic power generation.

Hugo's first major publication was the book "Dynamic Circuit Theory", published by Pergamon press in 1965. This 656 page book is not only about circuit theory, but has material on electric machines, induction motors, control theory and transformers. It is packed with mathematics. When I borrowed this book from the CSIRO library where I work, I noted that the borrower's card was crammed full of names of people who borrowed the book. Many of the diagrams in this book were drawn in Indian ink by Renate, his wife. A second book of Hugo's is "Energy Conversion Statics", published in 1969. In a recent Google search, I found that Hugo has written a third book, published only after his retirement, on Hugo's research specialty "Magneto-hydrodynamic Electrical Power Generation". I was surprised that Hugo had not proudly shown a copy of this book to me on any of my visits to his home after his retirement. Hugo was not that type of person. Renate had to make quite a search of his office, just to find a copy of the book. Of course, Prof. Messerle has many papers published in scientific journals and International Conference Proceedings, for

example on plasma interactions with electrodes, stability theory of MHD "Disk" generators and circuit interruption. He also wrote papers on more general subjects such as "Restructuring Tertiary Education in Australia".

Hugo Messerle was Head of the Department of Electrical Engineering at the University of Sydney for almost 20 years. Prof. Messerle calmly shouldered the onerous and stressful duties of Head of Department such as allocating teaching duties among staff members, recommending particular staff for promotion, organising new courses within the department and representing the department on numerous university committees. Hugo was quiet, not autocratic, had an admirable emotional stability, and was an effective leader who had the consideration of his staff at heart. Hugo also made significant general contributions to university and public life: he was founder and chairman of the Committee on Sustainable Development of the Academy of Technological Sciences and Engineering. He was the founding Director of the Electrical Engineering Foundation at the University of Sydney, Director of the Board of the Warren Centre, Chairman of the Computer Research Board and set up the International Liason Group on Engineering Education. He was also a member of the International Current Zero Club. He was awarded the Medal of the Australasian Association of Engineering, the Centenary Medal of the IEEE of USA and also a Centenary Medal of Australia.

Finally we come to Hugo's contributions to his research field of magneto hydrodynamic power generation. Australian electric power is largely generated from the burning of coal to make steam. The possibility of doubling the efficiency of generating electric power from coal, using magneto hydrodynamics, has been investigated by large research groups in USA, Europe, USSR and Japan for many years. Hugo championed this research and had his own research group in this area at the University of Sydney, doing both theoretical work and also experimental investigations at the old White Bay Power station. Hugo participated in con-

ferences and meetings overseas in this field, and also invited many research leaders such as Prof Eustis from Stanford, USA, Prof Shelkov from Moscow, Russia, Prof. Shioda from Japan and Prof. Rosa from USA, to visit Australia. Prof. Messerle was elected Chairman of the UNESCO International Liason Group for MHD Power Generation for many years, an unusual honour for an Australian for a committee with membership from US, Europe, Russia and Japan. The concept of MHD power generation involves plasma moving at supersonic velocities in a magnetic field, with the possibility of doubling the efficiency of generating power. It now appears unlikely that this concept will be used, one reason being that "dirt", present in all coal, condenses at the electrodes of the MHD duct as slag. Either the slag is conducting, in which case the electrodes are shorted out, or the slag is an insulator, in which case no current flows to the electrodes.

Several months ago, at an International Plasma Conference in Japan, the Plenary Lecturer described current plans for a manned space mission to Mars. The method of propulsion of this vehicle is to be through the use of plasmas moving at super-sonic velocities in a magnetic field from super conducting magnets. This technology involving high temperature plasmas, is essentially the same as MHD technology on which Prof Messerle spent much of his life. Thus instead of this technology being used, as was Hugo's aim, to convert mechanical forces into electric power, it may be used the other way around, to convert electrical power to mechanical forces, to propel mankind to Mars!

Prof Messerle also made a remarkable contribution to the Uniting Church in Australia, where for almost 20 years he was chairman of the Continuing Education Committee of this church. This committee established administrative systems and means whereby members of the clergy of the Uniting Church could participate in continuing education throughout their professional lives to enrich their contributions to the Church and society. As a lay person of the church, this was a very distinctive contribution of Prof. Messerle.

Some years ago, while reminiscing to a friend about his early life, Hugo said "I landed in Australia speaking only German, with a small suitcase in one hand and a violin in the other". Now Hugo has left us. He leaves his wife, Renate, to whom he was married for 49 years, two daughters, Karin and Barbara, both of whom have PhD degrees and both of whom have husbands with PhD degrees, one being a Federation Fellow at ANU. Both daughters have two children. Hugo also leaves a legacy of almost 20 years as Head of Department of Electrical Engineering at the University of Sydney, and many research papers including three textbooks. He was a man of integrity, scholarship, and dedicated zeal in the pursuit of his research goal of improved efficiency of electric power generation, through the use of magnetohydrodynamics.

John J. Lowke
CSIRO Industrial Physics, Sydney
11.11.2004
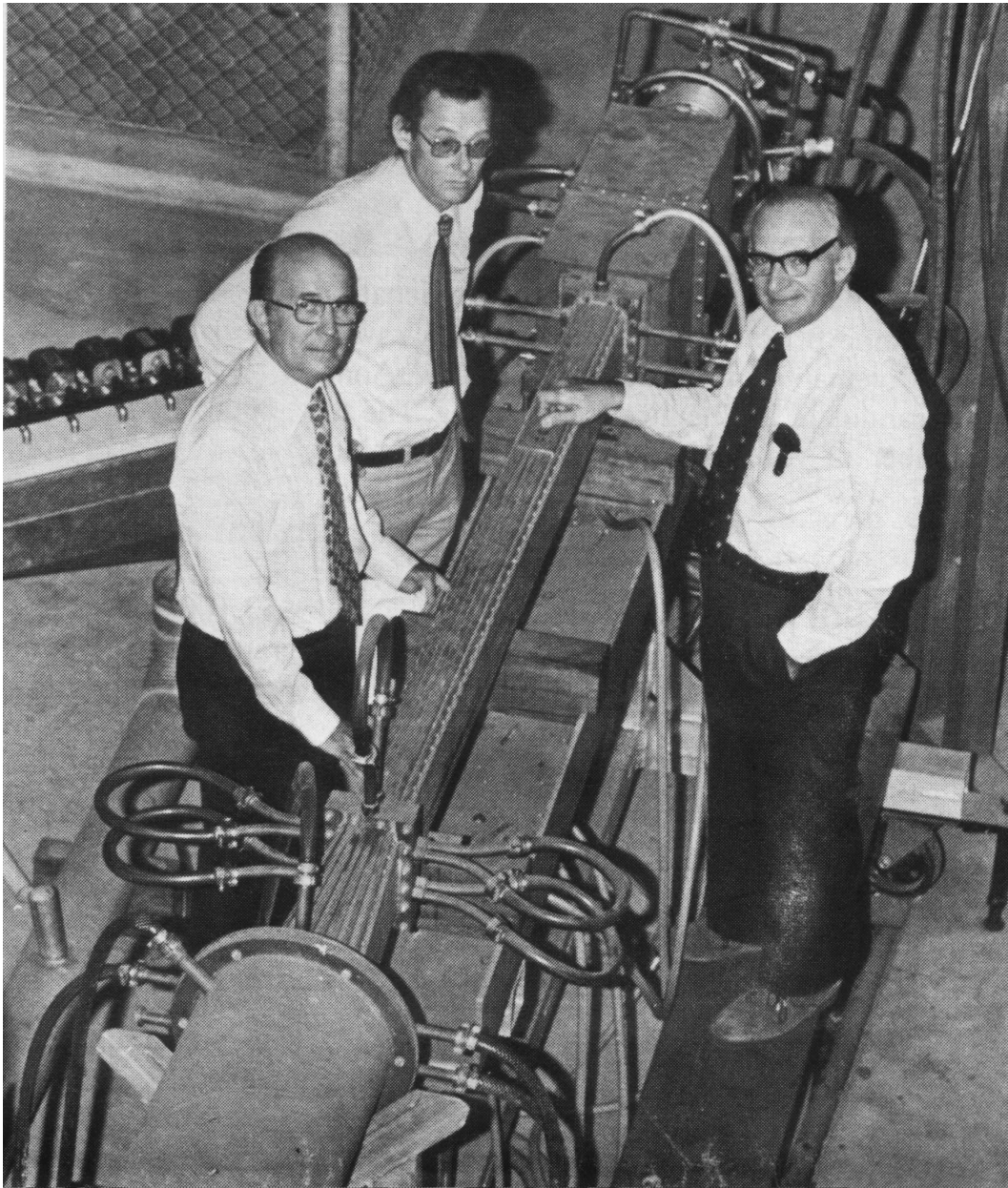
The photograph shows, Prof Hugo Messerle, Brian Campbell, then a Senior Lecturer in Electrical Engineering at the University of Sydney (Hugo's principal lifelong supporter of research in magnetohydrodynamic (MHD) research), and Prof Woitek Brzowski from Poland, who was an internationally renowned scientist in MHD who was visiting the School of Electrical Engineering at the University of Sydney as part of a collaborative research program. The three men in the photograph are in front of the experimental MHD duct built at White Bay Power Station in Sydney as part of Prof Messerle's experimental research program in MHD, 1979–1985.

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JOURNAL AND PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

NEW SOUTH WALES

THE ROYAL SOCIETY OF NEW SOUTH WALES

OFFICE BEARERS FOR 2005-2006

The Society originated in the year 1821 as the Philosophical Society of Australasia. Its main function is the promotion of Science by: publishing results of scientific investigations in its *Journal and Proceedings*; conducting monthly meetings; organising summer science schools for senior secondary school students; awarding prizes and medals; and by liason with other scientific societies. Special meetings are held for: the Pollock Memorial Lecture in Physics and Mathematics, the Liversidge Research Lecture in Chemistry, the Clarke Memorial Lecture in Geology, Zoology and Botany, and the Poggendorf Lecture in Agricultural Science.

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Three, single sided, typed copies of the manuscript (double spacing) should be submitted on A4 paper.

Spelling should conform with "The Concise Oxford Dictionary" or "The Macquarie Dictionary". The Systéme International d'Unites (SI) is to be used, with the abbreviations and symbols set out in Australian Standard AS1000.

All stratigaphic names must conform with the International Stratigraphic Guide and new names must first be cleared with the Central Register of Australian Stratigraphic Names, Australian Geological Survey Organisation, Canberra, ACT 2601, Australia. The codes of Botanical and Zoological Nomenclature must also be adhered to as neccessary.

The Abstract should be brief and informative.

Tables and Illustrations should be in the form and size intended for insertion in the master manuscript - 150 mm x 200 mm. If this is not readily possible then an indication of the required reduction (such as 'reduce to 1/2 size') must be clearly stated. Tables and illustrations should be numbered consecutively with Arabic numerals in a single sequence and each must have a caption.

Half-tone illustrations (photographs) should be included only when essential and should be presented on glossy paper.

Maps, diagrams and graphs should generally not be larger than a single page. However, larger figures may be split and printed across two opposite pages. The scale of maps or diagrams must be given in bar form.

References are to be cited in the text by giving the author's name and year of publication. References in the Reference List should be listed alphabetically by author and then chronologically by date. Titles of journals should be cited in full – not abbreviated.

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Erratum

**The last issue of the Journal had a correct Volume number but incorrect issue
numbers. Volume 138 Parts 1 and 2 should be Nos 415–416 and not 407–408.**