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Review of the National Innovation System
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I write as an individual with leadership experience in research, research application to gold exploration, gold exploration within industry, and research management (CSIRO, university).

Knowledge production lies at the heart of innovation, and is currently at some risk in this country for two reasons:

- *knowledge production* does not correlate positively with the size of a research unit, and
- *groupthink* remains a major barrier to innovation [i.e. knowledge production] especially in large research groups.

From these premises flow the two suggestions of keeping some space for small knowledge-producing research groups, and maintaining an active review of major research groups to monitor any decreases is knowledge production.

I draw my examples from the gold mining industry that has grown tenfold during the 1980s, and is now a leading export industry in Australia ($6 billion pa export). This success of gold is a formula that could well be followed for other commodities, both agriculture and minerals.

Knowledge production: Large research groups, such as Co-operative Research Centres, appear to struggle to generate the *knowledge production* anywhere near commensurate to their size and funding base. I suggest that this is because knowledge production commonly means overturning some existing theories, and that the large research groups are typically led by exactly those who have erected the same said theories that might need overturning.

In the life of a large research group, there are numerous stages where proponents of new or alternative theories can be, and are, disadvantaged because of their opinions, such as at original team and topic selection, continued employment, access to research funding, selection of appropriate topics, right to publish, and support or otherwise of ideas once they reach the public domain.

It is important that the above statement is read with the rider that large research groups have made enormous contributions in the area of knowledge application and knowledge diffusion. These last two areas of innovation appear to be the forte of the Co-operative Research Centres, and these Centres have filled an important gap here in the Australian innovation process in recent years.

2. Groupthink [i.e. deterioration of mental efficiency, reality testing, and moral judgment that results from in-group pressures] is the scourge of innovative thinking. Despite

denials of its prevalence, and belief that it is confined to the odd unsuccessful NASA space mission, groupthink is close to inevitable in the life cycle of many large and successful research groups. Although not necessarily described as groupthink, the examples of rigid research team thinking in Australian science over the last decades are well known to those close to the science disciplines.

Setting up for knowledge production: example of gold exploration success

The evidence from Australian gold exploration is that *knowledge production* is the realm of small (niche) research groups of 2-5 members typically. The success of the Australian gold industry through the 1980s displays this point admirably. Half a dozen breakthrough ideas revolutionised the gold exploration industry since 1980, and actually put Australia on the world map in this field (Hogan, L. 2004. "Research and development in exploration and mining: implications for Australia's gold industry" ABARE eReport 04.3). Three advances in understanding how gold deposits formed (timing, host rocks, alteration) were adopted in virtually all subsequent exploration programs through the highly successful 1980s and 1990s: they still underpin global exploration methods today (Phillips, G N, 2006. "Australia's declining exploration share: the problem, and a solution. III. Case history: the contribution of R&D to success in the Australian gold industry. Australasian Institute Mining Metallurgy, Bulletin 1, 39-42). Three further breakthrough ideas regarding the Australian regolith, and how to find gold in these environments, had similar profound effect on exploration both in Australia and abroad (dispersion, sampling media, landscapes). All six breakthrough ideas helped to underpin funding proposals for subsequent large research centres, but all six breakthroughs were generated by small research groups. Invariably, some of the large research groups were very successful in knowledge application and knowledge diffusion but they invariably failed to maintain the rate of *knowledge production* that had been present before their establishment.

Once recognised, the above barriers to innovation can be avoided by balancing the support for both large and small (niche) research groups (including down to the individual level). Groupthink is more difficult to avoid, and it is important to ensure that a new large research group does not simply take over where a prior group left off. If one line of innovation-seeking is not working (in mineral terms, this would mean a lack of discoveries and exploration success), then a whole new direction needs to be sought and almost certainly with a completely new research team.

The claims by CRC LEME recently that their regolith science has contributed to over sixty mineral discoveries appears to be a reasonable and accepted estimate. This is an incredible achievement. However, it needs to be remembered that the pertinent breakthroughs in thinking predominantly happened before the CRC was formed: this does not diminish the extraordinary role played by the CRC in knowledge dispersion, but highlights that the successes of the CRC in knowledge application and dispersion will always rely on new knowledge production. All three facets of innovation play a role, and each responds to different organization of research.

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