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# CAN WE MAKE CRIME PREVENTION ADAPTIVE BY LEARNING FROM OTHER EVOLUTIONARY STRUGGLES?

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Abstract
Crime prevention faces a perpetual struggle to keep up with changing opportunities for crime and adaptable offenders. To avoid obsolescence, it has to become adaptive itself. The task of keeping prevention up to date resembles other 'evolutionary struggles' such as biological co-evolution between predator and prey (eg continually sharper teeth versus continually tougher hide), or military arms races (eg more powerful guns versus heavier armour). These are both examples of protracted co-evolution of conflicting parties against a background of incidental disturbances which from time to time give the edge to offenders or to defenders. The disturbances in question originate from natural processes or human ones (such as the arrival of new technology). This paper explores the lessons for crime prevention which might be drawn from the other struggles at several levels: technology/ engineering, generic new methods of prevention and strategic concepts in prevention. An extremely wide range of possible lessons is identified which can take crime prevention a long way up the learning curve, but caution and consolidation are advised. Some ways of achieving this consolidation through systematic mapping are considered but not yet attempted. (*Studies on Crime and Crime Prevention Vol. 8 No.1 1999:27-51. National Council for Crime Prevention*)

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## INTRODUCTION

Offenders can fight back against crime prevention. The familiar concept of *displacement* describes the possibility that criminals, blocked in their first choice of target, will try different methods of attack, seek similar targets at other times and places, or change to another type of target altogether.

If we assume that criminals, while reasonably rational, are generally not highly-talented and innovative individuals, and if we take a short-term perspective, nothing changes very much in this cycle of move and countermove between offender and preventer. Crime merely gets shunted around a little, from place to place and from target to target. However, taking a longer-term view and focusing on the more intelligent, entrepreneurial criminals (cf Wiersma, 1996) we can see displacement as part of a wider, evolutionary, process in which offenders adapt their methods of attack to circumvent current preventive measures, and preventers in their turn readjust by creating new devices or employing new methods of defence. The offenders in their turn make further countermoves and the process spirals on indefinitely. This is a 'Red Queen's Game' (from Lewis Carroll's *Alice through the Looking Glass*), in which you have to keep running merely to remain in the same place (van Valen, 1973). Failure of preventers to keep up leads to obsolescence.

A striking example of this evolutionary process is described by Shover (1996), in the form of the development of safes, and safe-crackers. This struggle began in the mid-19th century, but culminated, in the last few decades, in the crackers' virtual extinction. By the turn of the 20th century efforts by safe crackers had required safe designers to use manganese steel for its resistance to drilling and fire. But after World War I, the spread of the oxyacetylene torch left safes vulnerable. This in turn led to the development of laminated safes with alternate layers of manganese steel and copper to conduct away heat. With attack by torches effectively rendered obsolete, safe-crackers from the 20s to the 50s switched their attack to the locks, developing techniques to exploit vulnerabilities (sometimes analysed by 'reverse engineering' - careful dismantling of legitimately purchased mechanisms) or even developing tools to pull the locks out. After World War II, carbide and diamond-tipped drill bits briefly rendered the safe walls vulnerable again, forcing manufacturers to develop new laminates which break most bits. The production of ever-more sophisticated alarm systems denied thieves time to work away at the safe undisturbed. Together, these developments meant that thieves who were unable to acquire expensive electronic equipment and specialist expertise to defeat the alarms had to give up safecracking.

This case study neatly illustrates how, under circumstances common enough to be of practical concern, offenders and preventers can become engaged in move and countermove in a ceaseless struggle for temporary advantage, in which social or technological *disturbances* shift the balance first in favour of one side and then the other. The design of the car, the banknote or the accounting system thus continually evolves.

In an earlier paper (Ekblom, 1997 [in knowledge base]) I argued that those of us responsible for developing crime prevention policy and practice have to learn to cope with adaptive offenders and changing opportunities for crime, by *gearing up* to become adaptive ourselves. If we do not, many crime prevention techniques will become obsolete or irrelevant. (Pursuing a similar line of thought, Cohen et al. (1995:216) argue that 'contemporary crime control policies are hopelessly static'.) The rate of obsolescence will depend on the kinds of offenders involved and their resources, and the kinds of social and technological changes that occur. What is more, the rate of technological change is constantly accelerating. This means that the 'breathing space', which we get from a new preventive method before it is bypassed, is tending to diminish. I proposed a range of ways in which we could gear up against crime - for example by reinforcing 'learning paths' to collect information on new vulnerabilities and new methods of offending and systematically feed this back to designers and others engaged in prevention. As well as reaction, we should also develop *anticipation* of new methods of offending, whether we boost this by helping designers to 'think thief' or more strategically link it to technology foresight (eg Drexler, 1996).

One suggestion I made was to learn from players in other, similar evolutionary struggles who are already operating adaptively, and who may have been doing so over the long term. Military arms races show many examples of castles versus cannon, tanks versus bazookas, planes with electronic counter-measures versus missiles with counter-countermeasures. The military has only had a few millennia to evolve equipment and tactics but *natural* arms races have been going rather longer. Co-evolution between *predator and prey* has at least 600 million years of experience to offer. But natural evolution is not simply a matter of 'medieval warfare' with increasingly better-armoured prey slogging it out against equally-improving armour-piercing capability of carnivores. The less dramatic struggle between plants and grazers is equally important (and may be a better model for property crime). The even longer struggle between *pathogens and immune system* has resulted in dynamic and adaptive strategies on each side. This has culminated in such sophisticated attackers as the HIV or smallpox viruses. Smallpox has about a hundred genes that interact with human defence mechanisms. In fact it has evolved *counter-countermeasures* to cope for example with a 'virus alert' chemical produced by infected cells, whose function is to warn nearby *uninfected* cells to activate their defences against virus attack. At some stage the smallpox virus 'stole' a length of DNA from the human host, which coded for the host cells' receptor molecules for the virus alert chemical. When the smallpox virus invades a host cell it can therefore direct the cell to produce bogus receptor molecules which blot up the alert chemical. This masks the alarm signal so that *uninfected* host cells are not made ready to resist the virus. Contrast this with mankind's so far primitive, 'one-shot' attempt to counter bacteria with antibiotics (although future possibilities are more sophisticated (Chin, 1996)).

This paper looks in more detail at the other struggles and begins to chart some of the lessons which adaptive crime prevention policy and practice could glean from them to accelerate its own learning curve. These lessons range from i) engineering and design principles together with the functional and economic tradeoffs that provide their problem-solving context; to ii) possible new generic methods of prevention; to iii) the struggle process itself - *running* arms races versus *avoiding* them. The aim is to generate ideas and stimulate lateral thinking in a deliberately speculative way. But it is also intended that these are to be the first steps in a more cautious and selective process of knowledge transfer. [Some ideas for taking this process forward are suggested in the unpublished Appendix, which also serves to direct the reader to a wider literature.]

Before embarking on the main text it is worth pausing to ask whether we really *can* learn from the other struggles. Is this a merely superficial analogy, with the attendant dangers of importing attractive but inappropriate ideas into crime prevention? No. While we must proceed with caution, I maintain that there is enough that is common to these struggles for crime prevention to learn many useful lessons. But what is, exactly, 'common'? *Protracted conflict between agencies which vary in their characteristics, adapt, differentially survive and replicate inherited or otherwise cumulatively-developed characteristics.* All the struggles (whether they are mediated by rational thought or some other process such as natural selection) are pursued through development in tactics, strategy, and evolution of design. All involve exploitation of disturbances on one side and sufferance of their consequences on the other. The fundamental problem faced by the participants in each struggle is identical: (i) how to maximise positive consequences and minimise negative ones using the minimum of resources, (ii) when the enemy is doing the same, (iii) against a background of disturbances which may favour, and/or be exploited, by one side or the other? Point (i) could be called mere 'trial and error' played out over the long term, but the other two elements introduce emergent properties.

Recent scientific and philosophical thinking about evolution provides some further intellectual underpinning for this attempt at knowledge transfer.[1] First, Dawkins (1976), in his concept of the *meme*, explicitly equates *ideas* - which can pass between people - as replicators and differential survivors that resemble genes, albeit evolving and adapting in a very different medium. Examples of such memes include anything from an advertising slogan or a song that is difficult to get out of one's head and highly communicable to other people, to a scientific theory that has survived rigorous selection procedures, to entire religions. In the crime context, examples of memes are criminal values and subcultures, methods of offending, or of prevention, and the requisite designs, tools and equipment developed by either side. 'Good' memes survive, and are reproduced through cultural transmission on the offenders' or the preventers' side, as appropriate; 'bad' ones are soon forgotten.

Second, Dennett (1996) identifies evolution as an *algorithm* - a formal process comprising a sequence of logical operations that can be counted on to yield a certain sort of result whenever it is 'run'. An important feature of algorithms, which derives from their logical nature, is their *substrate neutrality*. That is, the medium in which the algorithm operates on its inputs does not significantly affect the product. For example, adding 2 + 2 still gives the same answer whether done through mental arithmetic, counting fingers, an abacus, pencil and paper, a pocket calculator or a computer. I do not think we can hold to the extreme position that the algorithms in the various struggles are identical. Lamarckian transmission - of acquired knowledge from one generation to the next - is a feature of most human struggles, for example. We also have 'horizontal' transmission of knowledge among contemporaries - for example of how to pick locks or where the best places for stealing from tourists are. Nor can we assume that there is just a single 'evolutionary crime algorithm'. But we can conceive of a *family* of algorithms covering the various struggles which are closely-related enough to make similarities useful and differences stimulating.

## SOME OTHER EVOLUTIONARY STRUGGLES

The other struggles (Table 1) take place in the purely natural world, in 'humanity versus nature' or in the purely human world. In each case I have tried to identify crimes that are in some way equivalent to the *events* which are at the heart of each struggle - battles, infections, killing, grazing, cracking of codes and obtaining of information. But this is for illustrative purposes only. Particularly with the natural world, the resemblance is partial - the equivalent of the human concept of 'property', for example, will have different and far more restricted meanings in the natural world (Colinvaux, 1980).

TABLE 1. *Some other evolutionary struggles*

| **Realm** | **Struggle** | **Description and possible crime equivalent** |
|---|---|---|
| ***The natural world*** | *Prey v predators* | (confronters, trappers, dupers), mainly resembling crimes against the person - assault, robbery, homicide |

[1] A review of further supporting arguments is in Cohen et al. (1995). The authors conclude (p211): 'In sum, since expropriative crime strategies are transmitted primarily through cultural media, and culture is a system of inheritance, expropriative crime is tractable to evolutionary analysis.'

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|---|---|---|
| | *Plant v herbivore* | grazing- taking stored energy and materials from plants, resembling theft |
| | *Host v parasite* | parasitism by insects, tapeworms etc - resembling theft |
| | *Host immune system v pathogen* | infection by bacteria etc resembling robbery (overcoming host's defences) |
| | *Host immune system v viral pathogen* | infection by viruses, resembling fraud or embezzlement in misappropriation of resources for and control of production; computer hacking (breaking access and control codes), and computer viruses themselves |
| | *Natural 'theft or robbery'* | within or between species - eg birds taking each others' nest sticks, or robbing others' food in midair attacks |
| | *Natural 'fraud'* | birds taking nectar by pecking a hole in the side of the flower to avoid the effort required to pass on pollen, orchids pretending to be female wasps and cheating males of reproductive effort and opportunity. |
| | *Natural 'threat, assault' or killing* | conflict over territory, mates, food. |
| ***Humanity versus nature*** | *Disease control* | hygiene, public health, innoculation, vaccination, antibiotics - resembling prevention of theft/robbery |
| | *Pest control* | rats etc spoiling/ stealing crops or livestock, spreading human diseases, acting offensively - resembling prevention of theft /damage, disorder/ nuisance |
| ***The human world*** | *Military arms races and (counter)terrorism* | arms versus armour, missiles versus electronic countermeasures, manoeuvrability - resembling assault and prevention of assault, homicide, disorder, theft of property, coercion, control of production |
| | *War-games* | military training; evolution of new strategies in chess; computer-games of tactics and strategy |
| | *Economic warfare* | outgrowing the enemy or disrupting their economy (shading into real crimes like forgery or extortion) |
| | *Hacking* | shading into serious computer crime |
| | *Espionage* | military/ industrial, to steal information on resources, products, tactics and strategy, shading into theft of information/ obtaining it in preparation for crime |

In practical terms, if not conceptual ones, there is already considerable 'leakage' of ideas, equipment and skills from one human struggle to another. Criminals obtain surplus military weapons (for example from the former Soviet Union), World War II sonar has led to advanced burglar alarms (Shover, 1996), computer hackers open the path from computer crime to cyberwarfare (for example sending computer viruses to disable the enemy's air defences (New Scientist, 1992)), espionage supplies miniature TV cameras for use in crime surveillance - or by fraudsters stealing people's bank card numbers as they key them in at an Automatic Teller Machine. Finally, the military concept of *stealth* clearly connects with the original meaning of stealing - to move quietly.

WHAT KINDS OF LESSON CAN BE LEARNED FROM THESE OTHER STRUGGLES?

In what follows I set out a range of examples from the other evolutionary struggles, and begin to identify their lessons for crime prevention at several levels. But it is worth reiterating that this is the beginning of the exercise, and lessons for prevention may be half-digested or overly speculative in places, requiring some tolerance on the part of the reader. In what follows, for ease of reading, the terms 'defence' and 'prevention' are used interchangeably, as are 'offender','enemy', 'predator' and 'attacker'. Note, too, that from one example I sometimes draw lessons for understanding how *offenders* operate, and then in the next, I switch perspectives to the *preventer*. [(My use of the term 'preventer', broadly equivalent to Cohen and Felson's (1979) 'guardian', is explicitly defined in the Appendix.) ]

*Engineering/design principles and the functional and economic trade-offs they resolve*

Existing crime prevention methods can draw many lessons from the development struggles at the design and engineering level. On the natural history side, there is a developing discipline of *biomimetics* (e.g. at the University of Reading, UK) which aims to transfer knowledge from the biological world to technology. But transfer of learning from nature, the military or anything else has to be much more than the mere lifting of technology. Identifying the *functional and economic trade-offs* that military or natural design have to resolve is as important an input for crime prevention as the design concepts themselves. Military designers are well-aware of these issues, having to design equipment for extreme and often conflicting requirements to gain success on the battlefield without jeopardising their users' lives. Military aircraft designers in providing a combination of offensive and defensive capabilities, have to resolve severe and complex tradeoffs of *weight/ manoeuvrability/ damage resistance/ damage tolerance/ reliability/ cost.*

The field of evolutionary ecology is accumulating many examples of how selection pressure for survival and breeding success has produced creative and 'efficient-enough' resolutions of very similar constraints.

Here are some simple examples of straightforward engineering from struggles in nature. Seashell *spines* frustrate predatory crabs' claws whilst keeping down weight and use of scarce mineral resources (Vermeij, 1993) - providing lessons for target-hardening such as resistance to attack by pliers and other tools.

Inhabitants of the seashore, such as limpets, possess shells which grip rocks by suction and demonstrate *anchorage* that is *firm, but shock-absorbing, and releasable.* This might be applied to anti-theft designs.

*Slippery* chemicals from natural sources (e.g. used in eluding capture, preventing over-growth by seaweed, or trapping flies in insectivorous pitcher plants) may be useful for anti-grip/anti-climb coverings.

Incorporating *predetermined fracture points in targets of crime* (the lizard's detachable tail is an example) seeks to minimise damage during crime, and prevent thieves getting a firm grip on an object in order to apply force on it - for example, the door handle that breaks off and requires special equipment to replace it.

Of course, what is cost-effective, ethically acceptable or practicable as a solution in one particular context, in one of these struggles, will not necessarily be so in crime prevention. (However, the position will usually alter when new and cheaper technology arrives, as happened with vehicle security systems.) But (ethical considerations apart) the underlying *dimensions* on which the trade-offs must be done are the same. Some more complex engineering/ economic examples are presented below.

*Passive armour* often seems to go with an active defence in biology (and the military) - ankylosaurs were heavily-armoured dinosaurs that co-evolved with big predators culminating in Tyrannosaurus. They nevertheless found it necessary to supplement the armour by clubs and/or spikes on the end of their tails. Beetles have invested in repellent taste or offensive sprays as well as armour. Ten percent of the bombardier beetle's body weight is formic acid at 75% strength - an astonishing investment in security. (If a human carried a personal mace spray of the same relative weight it would be equivalent to struggling around the shopping centre with a large gas cylinder strapped to one's back). How do the economics work out? For crime prevention, this all rather suggests that passive target-hardening should usually be enhanced by active measures such as alarms and the help they hopefully bring. We should however be careful about applying this to all circumstances, since some armoured animals or plants have *not* needed to evolve any active capacity to respond.

*Creating or importing new crime preventers*
Caution is required in case creating or importing new crime preventers causes them to bring, or develop, their own agenda. Biological pest control against insects introduced the cane toad to Northern Australia, where it has become a serious problem itself. When, at the collapse of Rome, the Roman Army was recalled from Britain, the Britons bought in Saxon help against sea-raiders, to their ultimate regret. Vigilantism is a known issue in crime prevention, but others may appear - as with autonomous 'agents' - computer applications which may in future roam cyberspace looking for likely criminal transaction patterns and taking appropriate action. *Criminal* agents could similarly be developed to seek loopholes in financial systems. Penetration-testing software for Internet security can be thus misused.

To learn how to control such autonomous agents it may be worth looking to see how certain African Acacia trees control their ant 'security force'. The trees provide the ants with food and nests in swollen thorns, in exchange for defence against herbivores. The trees must balance encouraging the ants, against becoming the ants' food themselves. (According to the most recent research reported in *The Independent* newspaper, 10.7.97 they even produce a chemical at pollination time which temporarily fends off the ants to allow bees to visit the flowers.)

Anyone who has cut their hand on a blade of grass will have encountered 'phytoliths' - small pieces of silica which grasses incorporate to constrain herbivores' grazing. The extra wear on the herbivores' teeth causes them to incur greater effort and cost (in the shape of production of tooth enamel from what may be scarce resources of calcium and phosphate) in relation to reward. There is no direct physical crime prevention lesson from this, but it is a good lesson in the economic constraint of 'offending' through forcing the 'offenders' into a position of shortage of vital resources which they need to be effective 'criminals'

*New generic methods of prevention*

I began my search for lessons from other developments confident that I would find many ideas for new methods of crime prevention that were *generic* - that is, of a fundamentally new kind. However, fairly intense scrutiny of the field so far suggests that there are actually rather few generic ideas that human ingenuity has *not* already applied to crime and crime prevention. Even something so apparently exotic a defence method as the lizard's detachable tail has something in common with the police officer's tie, which is detachable to avoid strangulation by offenders. But finding non-obvious correspondences is, well, non-obvious and takes time and persistence. Systematic mapping of the kind suggested at the end of this paper may help this process. The few examples of new and near-new methods I have identified are listed below under points a) to f).

*a) Confusing and misleading offenders about location of target and points of vulnerability*
Glittering fish shoals, or dazzling zebra herds, make the target difficult to single out and to pursue.

Camouflaging intentions by feinted movements (e.g. the gazelle pretends to dodge to one side of the cheetah, and then immediately doubles back to the other).

Disposition of dummy tanks to give misleading picture of invasion plans.

Ink clouds, produced by squid, can offer enemies a dummy target (from some distance away) as well as obscurity. Long-tailed blue butterflies have pretend heads painted on the rear of their wings, which become visible when the wings are folded. Birds peck at these pretend heads, causing little vital damage, and the butterflies escape with their true head unharmed.

*b) Limiting the knowledge offenders can glean about targets and preventers by observation of activity patterns*
Radio frequency-hopping in military battlefield communications to force the enemy to search a wide spectrum in order to eavesdrop on commands.

Disguising the strategically-important structure of a military radio network by 'free-channel search'.

Frustration of terrorist attack by varying journeys and times of travel.

c) *De-escalation, conflict avoidance and conflict channelling*
Military/diplomatic conflict avoidance by confidence building, clear communication procedures (including hot lines) and detailed attention to how the other side may misinterpret actions as preparation for fighting.

Animals ritualising conflict to minimise damage to the combatants (such as stags clashing antler-to-antler); chivalric combat confined to the champions of rival armies. There are obvious lessons for shaping gang wars towards symbolic contests, although existing team sports such as football may be criminogenic for a small minority of supporters.

*d) Making the method of offending risky and untrustworthy to the offender*
The use, or the threat, of 'double agents' in spying (but note that 'sting' operations are already deployed in dealing with organised crime, and drug dealing - where co-offenders are actually police, or have a realistic likelihood of being the police).

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*e) Exploiting 'bunching' or prey saturation*
Turtle eggs, buried by the thousand in sandy beaches, all hatch at once, and the tiny young make their way down the shore *en masse,* under attack from hordes of seabirds. This seems suicidal, but it is to the prey's advantage, because far more would be eaten if the predators could pick them off one by one and digest them over several days or, on a longer timescale, grow in numbers on the rich pickings. This could apply in crime prevention, say, with tightly-bunching the release of some company share issue that may be vulnerable to fraud. Saturation clearly relates to reducing reward (cf Clarke's (e.g. 1997:18) sixteen-fold classification of situational prevention), but not at the level of the individual crime incident - rather at the level of the average *rate of reward* over a criminal career. This will affect the offender's decisions, but at a more strategic level than is usually considered in situational prevention - 'the good times in crime happen, but they are so rare I can't make a living from them'.

*f) Perceiving threats distally*
Sensors, which primitive organisms use to protect themselves from being eaten or injured, tend to rely on immediate physical contact with a predator, or on the occurrence of injury itself, to 'sound the alarm' and initiate escape or other defensive action. In humans such systems still function, sensing pain for example through direct heat or pressure. These are 'proximal stimuli'. As more sophisticated animals evolved, they developed an increasing capacity to perceive and respond to 'distal stimuli' - the *sight* of the charging rhinoceros, not the *crash*. These distal stimuli help to predict the proximal ones, alerting the potential victim whilst there is plenty of time and space to take avoiding action, or otherwise to make ready its defences. (The significance of the advantage bestowed by distal perception is evidenced by the fact that the eye has independently evolved many times in different biological lineages.) Most alarms used in crime prevention are proximal, like pain detectors - activated only when damage has been done: the window broken, the car driven away, the jewellery snatched. Developing automated security systems which perceive distal threats rather than wait for the pain seem promising.

*Running the arms race: Lesson 1 from the struggle process*

Interestingly, while it appeared difficult to discover many new generic methods of prevention, it proved rather easier to find more abstract, strategic ideas about how to gear up (and how *not* to gear up) against crime. These ideas come under two broad headings: *running the arms race*, discussed in this section, and *avoiding the arms race*, discussed in the next. (Here, I use the term 'arms race' to cover all the struggles, not just the military.) Sometimes the correspondences suggest quite specific lessons for crime prevention; in other cases, the examples do no more than suggest that a closer look at the processes underlying some equivalent struggle might be useful.

*Anticipating displacement and wider adaptation by offenders*

Can we predict how the offender will adapt to the *next* preventive measure? Are there any ways in which we can develop an overview of the process of *moves/countermoves/counter-countermoves*, and identify ways to keep up? Military arms races give plenty of examples of such cyclical processes: espionage/counterespionage, codemaking/codebreaking, Electronic Counter Measures, military boobytraps and anti-tamper devices. To speculate, there is probably only a small number of *archetypical games*, whether played in the natural world or the human, from which to glean insights. [A fuller discussion of *game theory* and its relevance to the evolutionary perspective on crime prevention is in the extra , unpublished Appendix. included here] Some examples follow.

It is possible to learn from cycles of *mobility/ stealth/ armour* in military history (Macksey, 1993). Medieval plate-armoured knights were rendered obsolete on the battlefield due to developments in firearms, which were penetrating but slow to aim and fire. Knights in armour were followed in the 16th-17th century by emphasis on lightweight mobility. Armour reappeared in the form of the World War I tank - which the arrival of the internal combustion engine enabled to be both armoured *and* mobile. Today, even the infantry are using armour again, due to the development of materials such as kevlar. Being both lightweight and resistant to penetration, kevlar in effect loosens the constraints of one particular tradeoff. The *naval* arms race has evolved in the same sequence, but out of step from that on land. Armour appeared in the mid-19th century, made practical by the arrival of cheap iron and steel, on the one hand, and made necessary on the other by improvements in artillery. (The very first 'ironclad' warship was French, and rejoiced in the name *La Gloire*.) In the light of torpedos and anti-ship missiles, particularly the more recent smart ones, navies are now *abandoning* battleship armour in favour of manoeuvrability, stealth and air defence. Airforces (and to some extent also the navy) are now opting for a combination of stealth, evasion and striking first.

Arms races can also be *projected into the future*. According to a study by Boeing (described in Kiernan, 1996) - in the not too distant future tanks will become obsolete. Cruise missile proliferation will lead to the loss of the US military advantage; this will be restored by about 2010 only when US finds ways of countering enemy cruise missiles, probably by laser weapons. But by 2025 proliferation of these laser weapons in their turn will lead to a further shift in the balance. Can we chart similar courses of development within crime prevention? Interestingly, in the next round of the UK Government's Foresight Programme it is proposed to have a crime reduction panel (Ekblom, Pease and Rogerson 1998).

We can also learn from *failures in vigilance.* One of the classic military failures in technological vigilance was the unpreparedness after World War I to combat the tank (there is a principle that generals seem prepared to fight the war-before-last. When criticising failures to anticipate offenders' moves, we should note that trial by hindsight is often unfair. How are the defenders, with partial information and with limited resources, to identify which possible advances in war, or crime, are worth gearing up against, and which can safely be ignored? Even supposing crime prevention experts could make such predictions accurately, how would they set about establishing their credibility with designers, design commissioners and investors so that these paid heed to their warnings? Encouragingly, IT-based systems are already entering this field where security is vital to business. Mondex, the experimental electronic payment consortium in the United Kingdom, considers security to be a 'moving target' and has a strategy of bringing out a new smart card chip every two years to keep one jump ahead of offenders (McCormack, 1996).

*The transient nature of opportunity*

Many opportunities in crime, warfare, growth and reproduction etc are not constant, but *transient*. Depending on one's viewpoint, these can be seen either as an advantage or a vulnerability. What could be called *'breakouts with transient advantage'* can be extremely important as a way of opening up new possibilities of offence or defence. The longbow in the Hundred Years' War between England and France rapidly overcame the armoured knight on horseback; the first deployment of the tank in World War I tore through barbed wire and rolled over trenches; and penicillin conquered many serious infections. But in all cases, sooner or later the opposing side developed countermeasures or carried on the conflict by different means. Longbows were replaced by firearms available to all European armies. The Germans dug their trenches wider (which the Allies initially dealt with by lengthening the tanks - neither of which countermoves could be pursued indefinitely!), deployed anti-tank shells, and developed tanks themselves (for World War II). Bacteria developed resistance to antibiotics.

In crime, one such breakout and closure is the sudden widespread realisation of a new vulnerability to crime briefly exploited by fraudsters or forgers, who have only a few weeks or months until the vulnerability is recognised and the loophole is closed. Fraudsters are probably aware that their window of opportunity is time-limited. Likewise, in World War II, the allies deliberately decided to deploy a particular radio navigation aid for bombers, on the calculating assumption that the Germans would take 6 months to work out how it operated and take countermeasures. In crime prevention, renewing computer passwords is a simple way of following this strategy - each new password buying a limited period of reduced likelihood of penetration. Some of these transient opportunities involve offenders, or defenders, escaping old constraints by an 'evolutionary leap' in their own capacity. Others involve going for a new and initially unprotected target, such as an exotic disease attacking people with no natural immunity. This resembles the 'crime harvest' on naively-designed mobile phones (Pease, 1997).

Transient vulnerabilities exist when the technology of defence, or prevention, is temporarily outstripped by that of offence or crime. Smart cards, designed for financial transactions, are protected by various codes. The power of codes to keep their secrets, and thus to protect users from fraud, is determined by the number of 'differs' - different code combinations. According to one view (Ward, 1996), smart cards are currently too expensive to encrypt beyond 10,000 precalculated code combinations or 'differs'. Given that there are 800,000 credit cards in circulation in the UK, the chances of fraudsters finding sequences which match those on stolen cards are not insignificant. However, in the near future, card processor chips will become powerful enough to build in *unique* ID codes, and the transient vulnerability will close. Others, of course may open (see, for example Anderson and Kuhne (1996), and Mann and Sutton (1998) on the vulnerabilities of the 'Dallas' smart card chip).

When designers and users have to decide, say, on how much security to build into a new product, or in deregulating some old financial system, how should they try to predict these transient breakouts and vulnerabilities? Should they take calculated risks in allowing such transient vulnerabilities, or should they try always to block the window of opportunity? How do offenders, for their part, cope with transience of opportunity? Are there enough temporary opportunities coming and going for them to make a living, swinging from one chance to the next? How does this relate to 'foraging' strategies of *opportunist omnivores*, like rats, which can survive eating most foods, versus *specialist feeders* such as koalas that eat only Eucalyptus leaves, of which they need a steady supply? And to the lack of specialisation among most criminals? At the broadest strategic level, those responsible for keeping crime levels low should seek to ensure that the *rate* of offender adaptation is less than the rate of development of new methods of prevention.

*The importance of variety*

In implementing situational preventive measures, there is a temptation to economise by going for *uniformity* - with every house in the neighbourhood being fitted with the same alarm or lock, for example. But such an approach may be especially vulnerable. From the burglar's perspective, this 'crack one house and you've cracked them all' opportunity is akin to a plant disease sweeping through a 'crop monoculture'. Some examples illustrate the importance of variety.

*Fixed defences*, however good in themselves, always suffer through declaring their hand and giving the attacker the initiative and the chance to plan. (Using a football analogy, this could be called 'the penalty-taker's advantage' over the goalkeeper.) The defences may, moreover, be built on false assumptions and may well become out of date before it is possible to replace them. Famous World War II examples are Singapore (massive guns faced out to sea, but the Japanese invaded by land); the Maginot Line built before the war to keep the Germans out of France (the Germans went round the end); and the powerful Belgian fort Eben Emael, where the Germans landed on top with gliders.

DNA in lymphocytes (a kind of white blood cell) is highly diverse, since the cells need to evolve rapidly to improve the body's immune response (Sangalli, 1996). This shows that having the *capacity to evolve, learn* *and upgrade* is as important as possessing any individual preventive or defensive feature which gives temporary advantage. The same strategy has of course been learned by the enemies of the immune system, the bacteria, viruses and other pathogens such as the malaria plasmodium (Brown, 1996b). Interestingly, mutability has now been designed into computer viruses, particularly with 'polymorphics', to outwit standard anti-virus software. And companies such as IBM are deliberately seeking to design a new generation of anti-virus software to emulate the immune system (Pritchard, 1996).

The more genetically *diverse* the potential hosts of disease, the more restricted is the scope for any one type of pathogen to attack them (Wills, 1996; Colinvaux, 1980). One example is a forest consisting of trees from many different species so diverse in habits, morphology and biochemistry that no one kind of pathogen would be able to invest in evolving a broad-enough toolkit of resources to attack them all. Each pathogen will thus be confined to a different, and dispersed, minority and its population will therefore be kept at low levels. This host diversity would keep **many** different kinds of pathogens at low numbers simultaneously. The benefits of such diversity may apply to design against crime, in terms of encouraging variety in the defences to be overcome, and variety of ways in which the stolen goods have to be enjoyed or safely and rewardingly disposed of.

*The importance of adaptability*

Variety is important in itself for the arms race, but in the evolutionary context, inheritable, cumulative variation is *the* ultimate source of adaptability.

Pathogenic bacteria that cannot cope with the body's defences quickly die out. And even in the military, once the need for a weapons upgrade has been accepted by government, given sufficient priority the entire range of obsolete weapons can be scrapped and the force re-equipped. The same does not usually apply to crime prevention, where the majority of property to be protected, and the security devices to protect it, are in many individual private hands. This leads prevention to be prone to *field obsolescence*, especially in circumstances where victims are shielded from the effects of crime by insurance (which acts as a significant block on selection pressure). The prime example is the time it is taking in the United Kingdom for insecure old vehicles to pass from the roads, even though most new vehicles are much more secure. Cohen et al. (1995:216) argue that crime prevention should 'outperform... the mutability of expropriative strategies.' One general means of doing so would be to *design-in upgradability* to products such as houses, cars and mobile phones. This would involve 1) having high-security components designed and ready to be produced, and 2) having the standard-issue product designed so that the security upgrade slots in quickly and cheaply - whether this is a better lock, a tougher window or a harder-to-crack code. The advantage here is that we only need to spend out on higher security when and where it is needed. This would fit in with current attempts to provide 'bronze, silver and gold' responses to repeat victimisation (Anderson et al., 1995). In fact, to come full circle, this is just how the immune system operates - swinging into action selectively, in a graduated way, and only in response to a challenge.

*Adaptability* also implies *avoidance* of *'phylogenetic constraint'* (Raup, 1993), that is where an evolved security or defence system becomes so complex and integrated, that radical redesign is impossible, only minor adjustment. Also implicit in *adaptability* is a*voiding* evolutionary blind alleys of prevention*;* or conversely, *exploiting* the blind alleys by shaping *offenders* into them.

*Controlling offender adaptation by understanding how it works*

Adaptation often involves *knowledge spread*, or its equivalent, and the appropriate defence is to *minimise the opportunities for the offender to learn or pass on that learning.*

The main medical approach to coping with bacterial resistance to antibiotics is to ensure that the bacteria are definitively killed by a *full-strength and full-length* course of treatment, before resistance can evolve. There is an equivalent experience in crime prevention. Clarke (1995a) speculates that the German decision to require steering column locks to be fitted on all cars broke the cycle of recruitment/knowledge transmission/innovation by car thieves and is responsible for continued low level of car crime in Germany. In the United Kingdom, by contrast, the slow introduction of steering column locks to new cars allowed instant displacement to old cars, continued recruitment of new offenders, and gradual innovation in techniques to overcome the locks.

Another way to prevent offenders' learning is restriction of certain defensive techniques to rare but vital occasions - including restriction of antibiotic use or saving up particular aircraft or other military technology for a major emergency. (Such special resources were described as 'silver bullets' by the former head of Lockheed's ('Skunk Works') advanced military aircraft research and development establishment (Rich and Janos, 1994).) Once used, and thus known by the enemy, the technique is no longer as effective. A related strategy to reduce offenders' opportunity to learn is the telephone banking procedure which *samples* characters from the customer's password - 'tell me the first and fourth digits only'.

Technology transfer may be prevented by '*capture proofing*' equipment. The equipment is made difficult to operate without training; spare parts are difficult to obtain; it self-destructs, or stops working without authorised use. (Attempts are being made to design guns that only fire for the legitimate owner, identified biometrically, e.g. by reading fingerprints like a bar code.) Medieval Chinese crossbows (James and Thorpe, 1994) were an example of fortuitous capture-proofing. The enemies of the Chinese, the Huns, were incapable of keeping the 'hi-tech' mechanisms in working order without workshops, nor could they use the short crossbow bolts on their own longbows. But the strategy of capture-proofing may be difficult to achieve whilst at the same time promoting market freedom for commercial and do-it-yourself interests. Ekblom and Tilley (1999, in preparation) expand on the neglected but important concept of the criminal's *resources for offending*, and how restricting such resources could play an important role in prevention.

*The importance of understanding mechanisms of attack and resistance*

Adaptation is usually achieved through the offender, enemy, predator or pathogen developing new means of attack or resistance. Studies of how the AIDS virus subverts and/or outpaces the body's immune system are at the centre of efforts to fight the disease.

Further examples are the medical researchers who are now seeking to overcome bacterial resistance to antibiotics based on knowledge of how the bacteria neutralise the antibiotics (Chin, 1996). More generally, the process involves *trying to identify methods of prevention, which pose problems that offenders cannot easily solve with resources they currently have available, or are likely to have in the near future*. With bacteria this is in principle straightforward. It is possible to develop multiple bactericidal chemicals, or 'antisense' RNA sequences which directly and very specifically target sites on the bacteria's' own DNA (Thompson, 1996). In each case this hinders bacterial evolution of resistance, which has to be done blindly one mutation-step at a time, where each step must confer immediate advantage (so-called 'local maximisation').

Can we identify hard-to-solve problems for humans, where offender and defender are of similar intelligence, and where both adopt more 'global' maximisation (taking two steps back to be able to move three forward)? What sort of 'asymmetries' can human defenders build into their preventive measures, so that it really is harder for offenders to develop ways of countering them, even if they know how the defence works? One example here is those types of encryption which rely on offenders *not* having massive number-crunching resources, and sufficient time, to break the code. Others may involve high-level biochemical skills and facilities (although even these may be available to terrorists or organised criminals).

*Looking at 3-level ecological relationships -e.g. plant-herbivore-carnivore, or herbivore-small predator-big predator*

There may be concepts to learn which help us understand the influence on offender decision-making of the triadic relationship of property owner/ thief/ police. Felson (1983) in fact considers such interactions and suggests some unexpected implications. By keeping *illegal* predation on the part of criminals from dominating the ecosystem, the police (by *legal* predation) make possible the continuation of those legal activities in society on which the criminals prey. In other words, the police act as a brake on overkill, allowing sustainable exploitation by offenders.

We may learn from translating the concept of a *disease vector* role to understanding the causation of crime. Possible crime equivalents that come to mind involve certain kinds of 'crime promoters' (people who inadvertently or deliberately make crime more likely [OPTIONAL IF APPENDIX [- a term defined further in the Appendix]]). Examples relevant to vectors include people who carelessly pass on computer viruses or passwords, those who inadvertently reveal when a house is going to be unoccupied, those who leave doors unlocked, or who put excessively tempting displays on shop shelves. *Disease control strategies* more generally have come to focus less on the properties of specific germs, than on the ways they spread and reach epidemic intensity. Such ways of spreading exploit disturbances introduced by economic development and land use, international trade and travel, and breakdown of public health measures. Karlen (1995) describes how a panel of researchers set up by the US National Institute of Medicine followed this approach in devising a strategy for handling the problems of emergent diseases, including development of a global surveillance system. Similar proposals for crime control, modelled on disease surveillance, have been proposed by Cohen et al. (1995).

*Offender replacement processes*
These are important, being the broad equivalent, in the world of offender-oriented crime prevention, of displacement in situational prevention. A widely-quoted example is with gangs (Ekblom and Pease 1995): arrest and remove the leader, and a new offender will usually rapidly fill the empty post. The same may apply to the drug dealer. There are ready equivalents in the military (with the captain killed, the second-in-command takes charge) and in nature.

Thus, for example, ecologists have removed all male robins (a songbird) from woodland, only to find that their territories instantly refill with 'spare' males who previously had no territory of their own.

Over the much longer term, if a predator becomes extinct, some other predator eventually evolves to fill the same, or a very similar *niche*. The most familiar examples are the replacement of extinct carnivorous dinosaurs by their mammalian equivalents. They have come to perform the same 'job' (catching, killing and eating herbivores), in similar circumstances and with very similar equipment (powerful legs, large teeth and claws etc). The lesson for crime prevention here may be that particular offending niches (Felson, 1983; Paul and Jeff Brantingham, 1991) will keep recurring, even if individual groups of offenders are removed by arrest or rehabilitation, or prevented from developing the propensity to offend by family or school-based interventions. The interesting question is where the causation lies - does the existence of a potential niche somehow 'call forth' potential offenders possessing particular resources? The Brantinghams put the issue nicely when they make the point (1991, p9) that '...reducing the crime problem is tied to modifying the niche'. [OPTIONAL IF APPENDIX [The niche concept is duscussed further in the Appendix.]]

*Shaping the offender*
One consequence of the strategies we choose for crime prevention may be to 'shape' offenders in a particular way - making them more adaptable or specialised, more violent or less confrontational.

The malaria plasmodium produces a range of proteins that it needs to invade its host, and to deflect the host's immune system. To produce these proteins it has about 100 genes which it uses to outwit the host's defences. It is possible that selection pressure by the immune system of the host species may have shaped the plasmodium's genes that encode its 'countermeasure' proteins, to organise themselves into separate sets, instead of being haphazardly strung together. This enables the plasmodium to become a master of disguise, in occupying the blood cells of one particular host individual. It can rapidly shuffle the proteins on its coat in response to repeated identification and attack by the host's immune system. Each time this happens, the immune system has to learn to recognise the plasmodium anew before it can mount a fresh assault.

On the crime side, this equates to 'selection pressures' from prevention and other means of crime control, forcing offenders to acquire a whole range of skills to overcome the various obstacles and risks put in their way. One of the areas of contention in evolutionary ecology is how species diverge. In particular, does selection pressure from predators on prey, or from dangerous or otherwise resourceful prey on the predators, sometimes cause one species to become two? The area where crime prevention could borrow theories from this conjectured process is the general issue of specialisation of offending versus generalisation. Shover (1996) distinguishes between those thieves who are able to make the transformation into the hi-tech world, and those - the majority - who are unable to do so by virtue of the limited cultural capital they possess, and who thus remain pursuing low-grade opportunities, with limited means. Pease (1997) makes a similar distinction.

A related set of ideas in evolutionary ecology is the controversial 'plus ça change' hypothesis (cf. Hecht, 1996). This holds that barriers to evolutionary change may be lower in a stable environment than in a more dynamic, disturbed one. In stable environments (such as rain forests), species can become specialists, maximising exploitation of a stable niche. In dynamic environments they cannot develop far along a particular evolutionary path (because the niche they are tracking may change, catching out the over-specialised) and only the less-efficient generalists survive in the longer-term. Nowadays we all endure rapid changes in, say, computer software, that leave us struggling to keep up. It is heartening to note that the criminal, too, is often likely to be a few upgrades behind the current version, and may have no time to learn about vulnerabilities before they are fixed or made obsolete in their turn. Thus, living in a time of disturbances could also reduce criminals' efficiency. The shift from purely mechanical devices to solid-state electronic equivalents has made reverse engineering harder for offenders without specialist resources (we can work out how a clockwork watch functions by taking one apart, but not an electronic one).

*Camouflage and mimicry*
Wall-safes disguised as electrical sockets, and swords concealed in walking sticks, are well-known. Disguise is likely to become more pervasive. Modern production methods mean that, in general, function need no longer closely follow form. The scope for camouflage and mimicry in crime and crime prevention (drawing on both military and natural examples) is thus increasing.

The possibilities and limits of *Batesian mimicry* (harmless creatures free-riding on the reputation of the serious predators they mimic) - apply to false speed cameras etc. But the natural world suggests we should place little hope in burglar alarm boxes made from biscuit-tins. Signals tend in nature to evolve as costly, wasteful or even dangerous to the signaler, to ensure the *credibility of the message*. For example, certain insects carry a massive and ungainly 'flag' on their leg indicating distastefulness; and a hunted skylark acts recklessly to show the predator it is fit and not worth pursuing. This is perhaps akin to '*discouragement*' (indicating 'reward unlikely') rather than *deterrence* (indicating risk to the predator). Bluff deterrence does occur though with, for example harmless (clearwing) moths which resemble stinging hornets and 'eyes' on the rear wings of other moths which are displayed in a surprise flash. But again these have to be of good quality to convince experienced birds.

There are possibilities of *speeding up the offender's learning of avoidance through signalling conventions* as with *Müllerian mimicry*. Here, for example, all dangerous or foul-tasting insect prey come to adopt standard black and yellow or red warning signals to minimise damage to individuals from naive predators. The flashing red light on armed car alarms, and the sticky 'alarmed' label on the driver's door, seem to follow this principle. Perhaps there is more to the human side of deterrence - evolutionary psychologists might suggest that we are predisposed to see certain signals as menacing. These will have greater impact on offenders than other types of signal. Offenders' fear in the crime situation is a weakness that is insufficiently exploited in crime prevention (Cusson, 1993).

*Partnerships*
In nature, *partnerships* are important for enabling 'leaps forward' in evolutionary success. One defensive example is hermit crabs, living in borrowed seashells, with a stinging sea anemone growing on the 'roof' to keep predators at bay. Another, predatory instance is dwarf mongooses - small mammals living on the African plains. Mongooses flush out insects and reptiles, while ground hornbills - large birds with a higher vantage point - keep watch for predators such as hyenas, and share in the feast. There may be crime prevention lessons for understanding how offenders pool skills *ad hoc* or more systematically through organised crime, how the costs, benefits and risks of these strategies work out and how they might be manipulated. Also (partnership being a significant trend in prevention), there may be specific lessons for crime preventers.

*Avoiding the arms race: Lesson 2 from the struggle process*

Avoiding arms races is better than running them. As an object lesson in the futility of arms races, where all advances by one or other side are transitory, consider a Tale of Two Pelycosaurs. Dimetrodon - a carnivorous reptile of some 250 million years ago, evolved a sail-like solar panel on its back, whose function was probably to warm the animal up earlier in the day, enabling it to catch its still-lethargic prey. Edaphosaurus - the prey - *also* evolved a sail.... So learning from the ways arms races start, or fail to start, or stop, is important for crime prevention.

*How arms races start*

The start of arms races is well-documented for the military. Biological examples are inevitably more conjectural but may offer more abstract, transferable theory.

Arms races start in various ways. The role of citizens' fear of their country becoming vulnerable through being technologically overtaken by the enemy seemed important in several contexts: fueling military arms races in the 19th century (Macksey, 1993); the Anglo-German race to build bigger Dreadnoughts (battleships) before World War I; and in the plugging of the so-called 'missile gap' of the Cold War (Rich and Janos, 1994). The fear was sometimes manufactured. Companies such as Krupp in the 19th century adopted what Bismarck called the 'see-saw' strategy - selling defensive weapons to one side in a local conflict, then selling more effective offensive weapons to their opponents... then revisiting the first side to sell them better defence. In the crime prevention world, the see-saw strategy is unlikely, but unscrupulous private security companies *may* foment fear of crime to encourage sales.

At a very general level, some evolutionary theorists (eg Vermeij, 1994) see a number of reasons why 'evolutionary gridlock' can be replaced by an arms race. The gridlock happens because adaptive improvements in any direction away from the status quo are constrained by conflicting functional demands on designs and behavioural strategies. The organisms in question are caught within a web of trade-offs in which they have to strike compromises. Starting an arms race depends crucially on relaxing these trade-offs. Such relaxation can occur in several ways: (1) adaptive breakthroughs or 'key innovations' that enable previously linked traits (like weight and impenetrability) to vary independently; (2) entry into mutually beneficial partnerships with other organisms (discussed above); (3) increases in metabolic rate, perhaps introduced by some disturbance in the environment such as a warmer climate or more nutrients (Vermeij, 1994). Similar factors may apply with the military. The arrival of cheap steel, produced by the Bessemer process, boosted the later 19th century naval arms race (Macksey, 1993). There are intriguing connections to be made with long-term links between economic growth and the crime rate (Field, 1990). For preventers and offenders alike, innovation, specialisation and counter-innovation can perhaps only come about when one or both parties are operating above the 'breadline' and can afford to invest in development.

*Arms races poised at the brink...or avoided*

Under some circumstances it may not be sensible to use a particular preventive method intensively in the hope of obtaining a 'knockout blow' against offenders. The blow may only give temporary respite or may even make things worse. As the following examples suggest, over-use of a preventive or defensive method may serve only to initiate an arms race, to provoke another move in one that is already under way, or to make room in a niche for more rapacious offenders.

On the crime side, ways exist to reduce the severity of hacking attacks on Internet Web sites. But there is a fear that hackers would probably respond to the implementation of such measures by adopting more powerful tactics (Brake, 1996). This could be called the 'out of the frying pan into the fire' problem.

Opponents of the US Star Wars anti-missile programme argued that it would merely boost the arms race (but in retrospect, perhaps, the Soviets could no longer afford to keep up their investment).

The Pentagon is currently considering vaccinating all troops against anthrax. But there is concern that this could send the wrong message to other countries that the USA is preparing to fight germ warfare.

In biological evolution, there may be a tendency for *incumbent* species to prevail in occupying a niche, even if they are not the most efficient exploiters (cf Vermeij, 1994). Only significant disturbances may depose them - but in so doing, this may allow more efficient or rapacious species to displace them. In crime, the same could apply for example to the control of gang problems - 'better the Devil you know, than the Devil you don't'.

One strategy to minimise evolution of antibiotic-resistance among bacteria is neither to restrict antibiotic use nor to use overkill doses, but to use small doses which put minimal selection pressure on the bacteria. This just tips the balance in favour of the body's own defences.

The last example suggests that what may be more appropriate for prevention is to use the intervention not as the illusory knockout blow, but as a kind of 'low-level brake' on offending. Here, it would serve just to increase risk and effort or decrease reward sufficiently to 'wear down' the resistance and motivation of offenders, especially if used in conjunction with other preventive methods; but it would provide insufficient 'selection pressure' to force the offenders to adapt, given other constraints acting against change on their part. They would thus remain inefficient. Wortley (1998), adopting an evolutionary analysis similar to the present one, also notes that 'too hard' a level of control is frequently the end point of a 'crime strategy/prevention strategy spiral' of the kind envisaged here.

*Successful non-starts of arms races*
Fortunately, arms races are not inevitable, as the following examples show.

In the 1920s, following a treaty involving US, UK, France and Japan, these nations successfully avoided building battleships (although most countries sneakily developed aircraft carriers, which were not covered by the treaty) (Macksey, 1993).

With a few exceptions the Geneva Convention process has succeeded in preventing the use of chemical and biological weapons; non-proliferation of nuclear weapons has similarly had some success.

In 17th century Japan, Shoguns drove firearms out of the country, and kept them out for 200 years. They preferred swords, in the use of which they happened to be expert (Keegan, 1993).

Seashells and crabs on the Pacific coast of North America started an arms race, with tougher, spiny shells and stronger claws respectively - but their Atlantic cousins did not (Vermeij, 1993) - why?

But conditions can change and a stalled arms race may start at any time. If, as considered above, the existence of the niche 'calls forth' the criminal behaviour, then the sensible strategy in avoiding arms races would be to try to identify the elements of future criminal niches *before* they come together and engender a self-perpetuating tradition of offending, a body of skills, associated criminal service providers etc. This would involve some kind of crime impact assessment, but instead of focusing narrowly on individual products or services at risk of being stolen or misused, it would have to be fairly wide-ranging. It would mean considering the range of resources available to potential offenders, including facilitators such as tools and weapons, the range of likely vulnerable and attractive targets, and the range of likely crime preventers and promoters with the potential to hinder, or help, the criminal to exploit the opportunity. This linking of many threads would be a fairly demanding task. [OPTIONAL IF APPENDIX] [A conceptual framework for drawing together these understandings, based on just such a *conjunction of criminal opportunity*, is described in the Appendix.]] While some future conjunctions of opportunity would be obvious, many would not - and in effect an army of entrepreneurial offenders could also be searching them out at the same time. A small number of systematic, expert preventers would be pitted against a potentially large number of offenders - rather similar to the thousands of people in medical science pitted against the billions of bacteria all poised to try out new opportunities armed with new mutations.

*How arms races stop*
In general the reasons for cessation are that game strategies cease to be profitable, alternatives to conflict emerge, the growth of trust enables both sides to simultaneously switch to co-operation, or trade-offs increasingly constrain one or other side. Natural history and the military world again supply examples.

Cheetahs, in pursuing gazelles, can go no faster without becoming so lightweight that they risk damage from prey, or excessive theft of the prey they so laboriously catch, by carnivores such as hyenas, which are both heavier and operate in groups.

Modern battlefield helicopters such as the Apache have now increased in complexity, weight and cost to the point at which questions are being asked about their cost-effectiveness (Macksey, 1993).

The SALT process succeeded in slowing the US-Soviet arms race when both sides realised current levels of Mutually Assured Destruction were sufficient; the arrival of the concept of 'nuclear winter' also made both sides stand back from the race, each aware that the other knew the risk and shared the horror at its consequences.

As a corollary to evolutionary theories of arms race *starts*, trade-offs increasingly *constrain* arms races when available resources shrink. In such circumstances, the predator or prey that is most functionally-specialised, most highly 'escalated' in terms of investment in means of attack or defence, and most demanding of energy, is the one most prone to extinction (Vermeij, 1994). The vulnerability of the military might of ancient Rome to economic collapse is a possible parallel.

*The determinants of 'equilibrium' or stand-off positions*
In the short term, equilibrium of biological selection pressures can occur when the expense for the prey of additional investment in defence outweighs the cost x likelihood of falling victim, and when the benefit to the predator of being able to catch slightly faster prey is similarly outweighed by the expense. This relates, in crime, to van Dijk's (1994) explanation of why particular crimes occur at particular rates. However, for crime as well as other struggles, such equilibria are always *provisional*, and *precarious*, because they are merely awaiting the next significant disturbance to tip the balance towards the offender or towards the defender. And even in the absence of such disturbances, random permutations within the normal range of events can tilt the balance one way or another (Raup, 1993). The disturbance in question could be an unlucky encounter with disease in a threatened bird population, or in the criminal world a string of lucky arrests which eliminate a particular specialist criminal trade. Unlike the extinct bird, the criminal trade could of course be brought back from extinction - but this could involve a considerable learning process before the new offenders became proficient, and perhaps the re-establishment of a network.

## CONCLUSIONS

This exploration of equivalencies between crime prevention and other evolutionary struggles has been a rapid and unashamedly speculative skim over very complex and varied ground. But I hope I have demonstrated that the evolutionary perspective is one that we need to adopt in crime prevention to keep up with *our* opponents just as the military, medical and agricultural scientists, predators and prey, or bacteria must with theirs. The evolutionary approach offers a range of benefits for prevention. It poses new questions, and it helps us to develop the concepts to generalise from the rather limited set of specific examples we already have in prevention. It indicates possible solutions to contemporary preventive problems at a range of levels. These levels comprise technology/ engineering/ economics; generic new preventive methods (although in this case rather less than anticipated); and the very strategic level of running, or better still avoiding, the arms race, and managing the obsolescence of solutions.

A fundamental policy question raised by the vision of a perpetual crime prevention struggle is simply 'why bother developing new security techniques at all if they will inevitably lose their effectiveness or become irrelevant? The answer is, of course, that if we did not attempt to stop crime, even with only short-term success, it would grow unchecked, ultimately with devastating consequences. (Clarke (1995b) illustrates the crime growth problem on a local level with an example of 'slugs' fraudulently used to obtain tickets and change from London Underground ticket machines. Wider, national-level examples of failure to stop the growth and spread of crime are to be found in South Africa and Russia today.) Ekblom (1999, in preparation) sees the halting of such runaway growth as a distinct strategic feature of crime *control* as opposed to merely crime prevention or reduction.

The most strategic issue of all in running the arms race is how to live with it and how to ensure that the balance is tilted as far as possible, for as much of the time as possible, in favour of preventers. The more we succeed in achieving this goal, the lower we can keep the crime rate over the medium to long term. (Holding the crime rate within tolerable bounds is another aspect of the crime control perspective.) Keeping the balance tilted means exploiting the advantages we, as preventers have, and making the most of offenders' constraints and weaknesses by using the kinds of strategies and tactics set out above. What are the preventers' advantages? We obviously have state power and resources, and the moral support of the majority of citizens. We also have trust and are promoting organised collaboration between government, agencies and the general public. We are developing a better understanding of the causes of crime and the principles of intervening in the causes systematically, with the aid of research and evaluation. In this, to borrow a vision from engineering science (Hapgood, 1993), adaptability comes from being equipped with principles capable of being applied to many problems rather than fixed expertise in any one field of technology that could sooner or later be bypassed.

Unless organised crime grows significantly, most of these advantages will remain with the preventers, and we should actively ensure they do - by, for example, promoting *trust* among honest citizens (by building community life) whilst deliberately sowing *mistrust* among potentially-organised offenders such as drug dealers. We are, though, constrained in our turn by the need to reconcile good crime control with other valued goals, such as a free and open democratic market-oriented society that values innovation and technical development. In this respect, how the race is run is thus just as important as whether, at any particular moment in history, we are ahead. The real challenge is to find ways of controlling crime whilst simultaneously promoting our evolving *legitimate* way of life.

We have seen from both military and natural historical examples how arms races are not inevitable. But applying this to crime prevention is difficult. It is easy to dismiss the military examples by saying 'of course, crime is an anarchy - we can never envisage anything like representatives negotiating treaties'. However, a kind of tacit arms-race avoidance *does* seem to have happened in UK with both police and offenders restricting the carriage and use of guns. Perhaps this is because it is such a major step up for both sides. Whether this stasis can be maintained remains to be seen. (It will be interesting to observe what happens as incapacitant sprays are deployed by the UK police. Since this is a smaller step, will escalation of move and countermove now happen?). And to let nature have the last word, the Atlantic seashells and their crab predators mentioned above must have avoided an arms race through the operation of some game-theory-type process. Presumably they had no recourse to a treaty!

*Next steps: mapping the other struggles onto crime prevention*

Exploration should be followed by consolidation through a more reflective and systematic appraisal. One way of doing this is through mapping. To get the best out of any mapping exercise, we need two key ingredients: i) a systematic framework describing all aspects of *prevention*; ii) an equally-systematic and concise way of describing the *evolutionary processes* in each struggle. Together, these confer two advantages. First, mapping enables us simply to find what aspect of prevention is informed by, say, one stumbled-upon example from natural history. Second, it helps us prospect systematically in these other struggles for nuggets of learning. Third, if we cannot find a suitable pigeonhole in prevention for a likely strategy from another struggle, this forces us to become aware of any *gaps* in crime prevention thinking. In the unpublished Appendix I look ahead to some possibilities for mapping, using my own 'conjunction of criminal opportunity' framework of prevention (Ekblom, 1994, 1996, 1997, 1999 in preparation – in knowledge base), Paul and Jeff Brantingham's (1991) appropriation of the ecological niche concept to crime, Dennett's (1996) concept of evolution as an algorithm, and evolutionary/ game theory approaches to crime prevention developed by Cohen, Vila and Machalek (1995) and collaborators. To complete the maps and do the mapping is for another paper.

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APPENDIX: CONCEPTUAL TOOLS FOR MAPPING THE OTHER EVOLUTIONARY STRUGGLES ONTO CRIME PREVENTION *[NB this bit will not be published in SCCP]*

The primary means of organising the mapping exercise envisaged here would be my own (evolving) conceptual framework for crime prevention. This centres on the *immediate (or proximal) causes of the criminal event* (Ekblom, 1994, 1996, 1997, 1999 in preparation), which come together as the *conjunction of criminal opportunity*. Drawing on theory from both situational and offender-oriented prevention, this has both structural and process dimensions. Additional approaches likely to be of use are the ecological concept of niche, game theory, and evolution as algorithm. These, too, are briefly described below.

*Mapping the structure of crime prevention: the conjunction of criminal opportunity*

*Crime prevention* seeks to reduce the risks and seriousness of criminal events and related misbehaviour by intervening in their causes. This definition is simple, positive and non-restricting (it could apply equally to design approaches and to surveillance by CCTV, setting up a youth club, police patrolling or incapacitating offenders).

There is an infinity of possible causes of criminal events. Some causes are remote - such as abuse in childhood producing violent assaults in adolescence, or structural and technological change introducing completely new opportunities for crime. Others are closer to hand - the presence of a motivated offender in a suitable situation for committing a crime. It is these *immediate circumstances* surrounding the criminal event - the offender in the situation - which form the final point on which all the diverse structural, social, ecological and psychological causes of the criminal event must inevitably converge. Before discussing prevention through design or any other approach, we have to develop a clear picture of the criminal event and its causes.

A criminal event happens when the right *conjunction of criminal opportunity* takes place. Its elements are shown in Box A1 (an expanded version is in Ekblom, 1999, in preparation – in knowledge base).

Box A1 The conjunction of criminal opportunity

- A predisposed and motivated *offender*, accompanied perhaps by *facilitators* of crime such as tools, weapons or false security passes and other *resources* such as agility, knowledge or skills
- A vulnerable and attractive *target* of crime (person, object, service, system or information) in a vulnerable and attractive *target enclosure* (compound, building, room, safe)
- The absence of willing and able *crime preventers* - active roles in which people make crime less likely to happen - by shaping the situation before the criminal event (eg hiding valuables, providing access control), *intervening* during the event (eg sounding an alarm), or *reacting* after (eg pursuit, arrest, identification) - deterring the offender in anticipation and also affecting subsequent criminal events. Preventers can be formal (police, security staff, other jobs with a security element, crime prevention implementers such as community safety officers) or informal (eg residents protecting their own homes or property)
- The presence of unwitting, careless or deliberate *crime promoters* - active roles in which people make crime more likely to happen - by *shaping the situation* (eg leaving attractive goods visible in an unlocked parked car), *intervening* during the criminal event (eg egging an assailant on), or *reacting* after (eg conveying approval, buying stolen, pirated or contraband goods). Together, crime preventers and promoters can be called 'crime modulators'
- An *environment* logistically favourable for the offender and crime promoters and unfavourable for crime preventers (eg one that promotes concealment or inhibits pursuit); and one that may attract the offence (eg a wealthy neighbourhood) or motivate it (thin walls engendering conflict between neighbours over noise)

Prevention ultimately works by disrupting one or more elements of this conjunction, or by stopping them coming together. Readers will recognise the origins of this framework as an elaboration of Cohen and Felson's (1979) Routine Activities Theory, plus additional concepts from the Rational Offender approach (eg Cornish and Clarke, 1986; Clarke, 1995b), Brantingham and Brantingham's (1995) environmental criminology, and Farrington's (1995) integration of motivation and opportunity-reduction.

To this structural picture of the causes of the criminal event must be added a *process* dimension. As well as decision-making by the offender, there will be decision-making by the occupiers of the other roles; social interactions between the roles; and the offender's negotiation perhaps of several 'scenes' (Cornish, 1994) - achieving subsidiary events to prepare for the crime (such as obtaining a forged security pass) and to complete it (such as disposing of stolen goods). The outcome of one crime situation (success for the offender, or failure and arrest) will influence the probability and nature of future crime situations (eg through offenders learning or preventers exercising better prevention).

*Ecology: niches and disturbances*

The conjunction of criminal opportunity closely relates to the ecological concept of the *niche.* The niche is also a conjunction of the resources and motives of the niche *occupant*, and the properties of the niche *environment*[2] - the food to be exploited (by an organism with the relevant resources), the risks to be avoided etc. However, the niche is not a specific event (criminal or otherwise) but a generic set of events involving typical behaviour of a particular set of organisms in a particular set of situations. The significance of niches for crime prevention is discussed in Brantingham and Brantingham (1991).

*The notion of the disturbance* - in the form of changes to any one of the elements in the conjunction of criminal opportunity - was first raised in the main text, when discussing the arrival of a succession of new tools which could be used for safebreaking. These particular disturbances supplied *crime facilitators* (Clarke, 1995a; Ekblom, 1997). Other disturbances have supplied potential *offenders* themselves. For example, many soldiers discharged after the battle of Waterloo in 1816, with no means of earning a living, became vagrants and criminals - and similar processes may be at work today in South Africa and the former Soviet Union. Sometimes such people are equipped with resources for offending (such as unemployed school leavers sufficiently-skilled in computing to embark on electronic fraud). Still other disturbances have supplied new crime *environments* such as the Automatic Teller Machine, or new crime *targets*, such as the mobile phone. These conform to an all-too-familiar pattern (Ekblom, 1997; Pease, 1997) of *'naive' new target > crime harvest > retrofit preventive solution*. Earlier examples include the world's first prepaid postage stamp, the Penny Black of 1840, which rapidly had to become the Penny Red. This happened because people found they could wash off the (red) franking mark from the black stamp, which they then fraudulently re-used. (Black franking dye was however waterproof, hence the colour reversal.) Similarly *preventers* can exploit incidental disturbances such as the arrival of alarm systems originating from military technology, and cheap closed-circuit TVs with video-recording.

Ecological concepts of 'disturbed habitats' (such as landslip sites, where opportunistic, generalist, fast-growing or rapidly-dispersing plant species may exploit transient niches before the soil stabilises and longer-lived plants grow back) are also likely to be useful.

*Game theory*

One theme underlying many of the processes covered in the discussions of both running and avoiding arms races is the interdependence of move and countermove between defender and offender in jointly determining the consequences, or 'payoffs' for each party. Here, the most useful conceptual approach to framing and answering questions is that of *game theory*. As Cohen et al. (1995) argue, since game theory addresses the emergent process of the decision-making of two or more parties, it takes us a step beyond the single-actor focus of the Rational Offender approach.

The game of 'scissors, stone and paper' nicely illustrates the basic principle. If I choose 'scissors', then the outcome for me and for you depends on your choice too. If you choose 'stone', you win - my scissors are broken - but if you choose 'paper', I win. The outcome of the game depends, not on any individual decision, but on the *combination*. Basic models are deliberately simple (but can be rendered as complex as researchers wish). For a strategic example, consider a car thief (or, more likely, a subculture of car thieves

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[2] *Note that the environment* in ecological terminology is equivalent, from the offender's perspective in the conjunction of criminal opportunity, to the whole *situation*, including also the target and crime preventers/promoters.

working to some extent in communication with one another) and a car designer. The thief may face a choice of 'to invest or not to invest' in further expertise, equipment etc in overcoming vehicle security, and the designer may face a choice of 'to invest or not to invest' in improved security systems. If both decide *not* to invest in the arms race, then both, in the medium term, receive a moderately good benefit of avoidance of considerable effort and expenditure, while car crime levels remain fairly stable. However, if both decide to invest, each receives a moderately poor payoff of car crime remaining near the status quo whilst having to spend out respectively on improved crime facilitating tools and security measures. If the offenders choose to invest whilst the preventers do not, then (for some while at least) the offenders enjoy a large payoff of 'easy pickings', while car designers' products are increasingly stolen. Likewise, if preventers unilaterally upgrade their security, they enjoy much-reduced crime and car thieves lose out.

Cohen et al. (1995) rely heavily on an 'evolutionary game theory' perspective in understanding the development of crime patterns, and provide a good introduction to the extensive literature. They identify generic features of the tactics and strategies of offenders (their modus operandi) which can be used to understand and predict their moves and countermoves - they may be surprising, cryptic (hard to detect that a crime is being committed), deceptive, bold, mobile/ transmittable to other offenders, evasive (moving operations around to avoid detection and countermeasures in any one location), resistant (impervious to countermeasures), or - of course - mutable (capable of being altered to circumvent countermeasures).

To their picture, however, I would add a number of considerations to render the games more realistic:

- The need to take explicit account of the role of *disturbances* in continually adjusting the players, and the payoffs, in any one game matrix.
- Most of the synthetic games in research are run with *simultaneous* making of joint decisions by the players. *Alternation of moves* also needs to be taken into account.
- One complicating move offenders can always make is to *jump from one game to another* - from robbery, say, to theft. In ecological terms, the ability to occupy particular niches part-time and to move from one to another is one of the distinguishing characteristics of humans (Colinvaux, 1980) - the opportunist species *par excellence*.
- The significance of offenders having to operate not only against the targets (such as the victims of assault), but also against reacters (such as the police) highlights the importance of developing games of (at least) *three levels* (cf Felson, 1983; Vermeij, 1994). This could be studied by linking payoff matrices of several two-level games, such that while the offender is trying to win one game with the victim, he is simultaneously seeking to avoid losing another game with the police.
- Games research and simulation could be extended to study the effects of the resources (methods, skills, weapons and tools) available to the participants.
- Game analyses need to distinguish more clearly than they sometimes have in the past between mere *competition* for the payoff, and *conflict*.

These difficulties apart, one advantage of game analyses is that they can be computer-simulated to reveal their properties. This can inform policymakers of the possible effects of changing particular payoffs - such as the risk and magnitude of punishment, or the input of effort required to complete a particular move. An example of such simulation is in Bueno de Mesquita and Cohen (1995).

*Evolutionary theories*

Rival theories abound within the study of biological evolution. One significant example is that of *escalation* versus *coevolution*. Reviewed in Vermeij (1994), escalation sees enemies (competitors, predators, dangerous prey) as the most important agents of natural selection among individual organisms. Coevolution more simply, and more generally, holds that two interacting species change in response to each other. Escalation seems more germane to the arguments developed in the present paper, but any transfer of ideas from this field to crime prevention cannot ignore the rival camp. Interestingly, Vermeij (1994:232) argues that "In order to make headway in the study of coevolution and escalation, we need to study the sources, frequencies, and cost-benefit effects of selection. This entails careful observation of encounters between species, together with an evaluation of the effects of such encounters on survival and reproduction... Models should be constructed not only by expressing the net outcome of selection in terms of births or deaths or energy intake, but by evaluating systematically how encounters of various kinds affect opportunities for functional improvements among interacting species." If we translate selection in terms of fitness of offenders for occupancy of a particular criminal niche, as aided by development, retention and dissemination of suitable methods of offending and crime-facilitating tools, then the links to the other criminological concepts set out above are readily apparent. Particularly relevant are the links to the Rational Offender's decision agenda of minimising risk and effort, and maximising reward, for a given level of available resources.

*Characterising the struggle process: evolutionary algorithms*

The introduction to the main text discussed the utility of the concept of evolutionary algorithms for describing the respective struggle processes in equivalent, fairly abstract form. This exercise has yet to be attempted.

It is likely that in the crime prevention struggle, as in the other arms races, we will find algorithms operating at several levels. But identifying these algorithms is vital in helping us define the *differences* between crime prevention and each of the other struggles, as an aid to caution in importing ideas. For example, human offenders can survive 'lean' periods by sharing niches part-time, or switching to other niches (as already mentioned above) such as 'employee' or 'social security claimant'; most other life forms cannot (except perhaps for the case of the highly-adaptable rat, examples are usually rather limited in their scope: butterflies eating leaves as caterpillars, overwintering as inactive pupae, and breeding in their winged splendour).

*A grid*

Combining structure, niches, games and algorithms should enable us to draw up some kind of *grid*, to compare and contrast examples from the other struggles with the equivalent elements of crime prevention. The next stage would be to start filling the cells of the grid, by locating within it a collection of specific examples from the other struggles. The grid can be adjusted to accommodate to gaps in the current set of preventive concepts. At the same time, the correspondences must be assimilated, to draw out their contribution to crime prevention, whether method-specific or at the more abstract, strategic level. Face-value correspondences are relatively easy to identify. But caution is vital at this stage to avoid potentially costly mistakes from adopting the wrong lesson, or applying the right lesson to the wrong crime prevention task in the wrong context. Aids to caution would include a thorough understanding of both the 'exporting' example - its mechanisms and context, its trade-off economics etc - and the 'importing' aspect of prevention to which it is to apply. The knowledge we wish to borrow from the exporting field could of course be wrong. All of the fields I have covered are still developing (in some cases, excitingly so) and all have academic controversies of their own. And imports should always be provisional until piloted and evaluated.

Likewise, each human or human-nature struggle has its own *ethical* constraints - what is acceptable in war, espionage or pest control is not necessarily suitable for crime prevention. In most countries (but sadly not all), land mines, bugging suspect neighbours and high voltage fences in the suburbs are definitely out.