ORGANIZATIONAL CLIMATE,

PRODUCTIVITY AND CREATIVITY

IN AN R&D ORGANIZATION

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"*It is the inner-driven scientists or engineer who is truly creative"*

Creative thinking has been described as a special class of activity in which the product of the thinking has both novelty and value. Creativity in the R&D environment and how to encourage and support it has been the subject of much study over the years (Clarke and Reavley, 2001).

Creativity and productivity are important to an R&D-based organization if it is to survive in today's fast moving economy and rapidly evolving scientific/technological knowledge bases. Creative personnel are critical to the vitality of an organization's R&D activities.

It has been stated that a creative scientist is the result of a fortunate combination of intellectual characteristics, emotional dispositions, and a particular organizational climate that is favourable to him or her (McPherson, 1964). Westwood and Sekine (1988) argue that creativity in adults is an intrinsic skill, that can be stimulated or suppressed but not generated where it does not pre-exist.

Numerous attempts to identify people capable of creative activity and thought, by means of psychological tests, have generally failed. One reason is that creative behaviour at work is a function of both an individual's personal qualities and the environment within which he or she works. The potentially most creative people will show little signs of creativity if they are in an environment that represses creativity.

Demonstrated Creativity = f(Personal attributes, Environment)

While the intellectual and emotional characteristics of research engineers or scientists are generally beyond the influence of management, the degree to which the organizational or work climate encourages or supports creative activity is well within the ability of management to influence. Through organizational policies and procedures, organizations set the tone of the working environment, which in turn directly affects the level of creativity and productivity of the employees.

Numerous management researchers point out that to have a creative organization, you must first hire creative people. This is made easier if an organization has a reputation of supporting creativity. As Johnson (1996) notes, "*Creative organizations draw creative people".* While it is difficult to predict creative performance, management researchers have noted certain attributes that are associated with creative people. It is suggested that when hiring, these attributes be kept in mind.

CHARACTERISTICS OF CREATIVE R&D PERSONNEL

While it is difficult, if not impossible, to predict whether a person will be creative, management researchers have identified personal characteristics that are associated with people who have demonstrated creative ability.

Alfred E. Brown, former Director of Scientific Affairs for Celenese believes the following are characteristics of creative people (Wolff, 1979):

- intellectually curious;
- open to accepting new information;
- able to identify the real problem, and then define it accurately and clearly;
- highly sensitive to needs, usually spotting them before anyone else;
- can see connections between blocks of information and put them together to solve problems;
- unorthodox and anti-authoritarian, questioning conventional ideas and established concepts;
- mentally restless, intense, strongly motivated, and completely wrapped up in what they are doing;
- problem solvers rather than phenomenon-studiers, goal-oriented rather than methods-oriented; and
- not necessarily of high intelligence.

Brown states that the key is to identify and hire people with these creative characteristics.

Shapero (1985) considers that creative people:

- are attracted by the quality of the problem to be solved;
- are non-conformists;
- have little reverence for authority or procedures;
- are "short" on loyalty to their employing organizations;
- don't respond to the kinds of incentives that motivate others;
- are not moved by status;
- don't seem to care about what others think; and
- don't easily become part of a general consensus.

In their study of creativity in an R&D laboratory, Amabile and Gryskiewicz (1987) reported the following personal qualities described by their interviewees as being associated with highly creative scientists (Listed in order of the frequency they were mentioned):

Intrinsic Motivation - or being motivated primarily from within rather from external pressures; excited by the work itself, enthusiastic, and attracted by the challenge of the problem, having a sense of working on something important.

Ability and Experience - having special problem-solving abilities and tactics for creative thinking, having talent and expertise in the particular area, having broad general knowledge and experience in many fields, and being highly intelligent.

Risk-orientation - being unconventional, willing to take risks with ideas and money, is risk-oriented, is rebellious or brash, willing to try something new, and attracted to a challenge.

Social Skill - having good rapport with others, being a good listener and a good team player, and open to other's ideas.

Other Qualities - having persistence, curiosity, energy and honesty.

They found that the most frequently mentioned characteristic of creative scientists was their self- or intrinsic motivation. The relationship between intrinsic motivation and creativity and productivity has been noted by many other management researchers (Pelz and Andrews, 1976; Ekvall, 1983; Smeltz and Cross, 1984). Amabile and Gryskiewicz point out that an earlier

study by Andrews (1975) did not find "sheer brilliance" to be among the list of positive qualities of creative R&D scientists.

Westwood and Sekine (1988) believe creative R&D people have the following characteristics:

- a diversity of interests, with skills and contributions in several areas;
- a high level of enthusiasm and mental resilience;
- a relatively short interest span (months, not years);
- a disregard for authority and intolerance of bureaucracy; and
- a need for repeated expressions of appreciation and recognition.

Johnson (1996) considers that creative researchers have the following attributes:

- **curiosity**, an unending desire to understand how everything works;
- **confident** enough in their own ability to ask questions, which my cause embarrassment;
- **compulsive**, a need to act on their ideas as soon as possible;
- **resourceful**, able to work under less than optimal conditions, drawing resources from wherever available;
- **perseverance or effort**, ability to continue in an undertaking in spite of counter-influences, opposition or discouragement;
- **adventurous**, a yearning to try something new, to work on new problems; and
- **convergent thinking**, ability to take facts and experience in one area and apply them to solve a problem in a different area.

Characteristics of Uncreative R&D Personnel

Amabile and Gryskiewicz (1987) found the following to be associated with scientists involved with what they termed "low creativity events":

- being unmotivated;
- not being challenged by the problem;

- lacking courage in attacking a difficult problem or overcoming environmental problems;
- being pessimistic about the likely outcome of a project;
- being overly cautious and unwilling to take risks;
- complacent;
- motivated primarily by external factors such as money or recognition;
- lack of skill or experience in the field worked; and
- being inflexible and overly cautious in their thinking;

ORGANIZATIONAL CLIMATE

"For creativity and innovation to occur in a technical organization, upper management must have a desire to do new things" - M.M. Johnson, Research Fellow, Phillips Petroleum, 1996

As the above quote implies, nothing will happen if senior management does not strongly support it. This especially applies to creating a work environment that encourages creativity and productivity. Senior management's words and actions must, on a daily basis, reinforce the belief that the organization wants and needs its employees to be creative and productive, and that barriers that impede this will not be tolerated.

Many factors are involved in the overall description of an organization's climate or work environment. Some of the more important factors are (Osbaldeston, Cox and Loveday, 1978):

Amount of Structure - the perceived limitations of the work environment; the feeling of constraint in the work group; the extent of perceived rules, regulations and procedures.

Autonomy/Responsibility - the feeling of being your own boss and not having to double-check or get prior approval for your actions or decisions; when you have a job to do knowing that it is something for which you are accountable.

Reward/Recognition System - the feeling of being rewarded or recognized for a job well done; the emphasis on positive rewards rather than on punishment; and the perceived fairness of pay and promotion policies. Degree to which the reward system employs intrinsic versus extrinsic rewards.

Risk Avoidance - the extent to which risk taking is encouraged or discouraged; how failure or mistakes are managed; the general attitude toward taking chances and doing things in a different manner; and emphasis on an error-less operation.

Tolerance of Conflict - the general attitude of the organization towards conflict resolution; a feeling that managers and colleagues want to hear different opinions and are not afraid of constructive conflict.

Warmth/Support of Colleagues and Managers - the perception of working in a supportive atmosphere with cooperative attitudes, mutual trust and confidence among all organizational levels, and friendly, helpful relationships within work groups.

Existence of Standards/Pressure to Produce - the perceived importance of implicit and explicit goals and performance standards; the emphasis placed on doing a good job and the challenge represented in personal and group goals.

Identification With and Sense of Belonging to an Organization - the degree to which the employees feel that they belong to a respected organization and are valuable members of a working team; individual identification with and commitment to the organization's goals and objectives.

Information/Communication Channels - the perception of the adequacy of the provision and exchange of information throughout the organization; the validity and timeliness of the information; the freedom to go outside the formal organizational structure to obtain information.

Management Style - the extent to which management consults staff and involves them in decision making; the confidence held by subordinates in the style and effectiveness of management practiced by their supervisors.

It should be remembered that the quality of an organization's work climate as determined by these factors is in the eyes of the beholder, i.e., the employees. It is the employee's perception of these factors that is important, not a clinical measurement of these factors by senior management or an outside consultant.

Environmental Factors Supportive of Creativity

Numerous studies have shown the critical role that work environment or climate and managerial actions play in encouraging both productivity and creativity. The following are brief descriptions of some of the findings.

Freedom or Autonomy to Make Decisions

A common theme in the creativity literature is the granting of freedom or autonomy for the scientist or research engineer to either chose their own projects, or at the minimum to determine how the project is to be conducted. It will be noted that either freedom or autonomy is one of the factors mentioned in most of the lists of factors associated with creativity.

Isenson (1965) found a positive correlation between a laboratory's reputation for excellence and the degree of freedom it allows its scientists or engineers in the selection of technical paths towards stated objectives.

Amabile and Gryskiewicz (1987) in their study of 120 R&D scientists and creativity, found that the most important or primary theme associated with creativity was that of freedom; "*freedom in deciding how to best achieve the goals of a specific project*". They state that freedom is a powerful stimulant to creativity.

In an examination of a very creative and innovative company, Perry (1995) noted that the firm allowed its researchers considerable freedom to work on projects of their own choosing. They also bring in large numbers of new researchers annually, with older scientists moving on into development activities with their projects.

White (1996) notes, as many before him have done (e.g., Pelz and Andrews, 1976, Gupta and Singhal, 1993), that autonomy is "*a critical component of innovative thinking*". Thus effective R&D managers should favour an "autonomy-oriented" management style over one that is more control-oriented.

The greater the freedom or autonomy granted to a researcher, the greater will be their feelings of ownership of the project, with resultant feelings of job satisfaction.

However, many studies have shown that complete freedom can be as detrimental to creativity as a complete lack of freedom (Pelz and Andrews, 1976, Andrews and Farris, 1967, Amabile and Gryskiewicz, 1987). Bailyn (1984) suggests that the freedom to set the research agenda (strategic autonomy) should rest with the research manager, while the freedom to determine how a problem or project should be tackled, within organizational resource constraints (operational autonomy), should rest with the researcher. This will assure that any creativity forthcoming will be in line with overall organizational objectives.

Job Involvement

Job involvement or job satisfaction is determined to a considerable extent by management and the work environment. Enabling employees to obtain maximum job satisfaction from their work should be the goal of all managers. It is positively related to the energy and enthusiasm employees focus on task accomplishment. It is also an important factor in promoting good mental health (Clarke, 1971).

A study by Dewhirst (1973) of an American government laboratory showed that the importance of the R&D task was a major factor in determining the degree of job involvement displayed by R&D professionals as measured by absenteeism and turnover. Members of groups working on projects ranked high or moderate in task importance to the organization had nearly twice as many members who used only one day or less of sick leave per year. Among groups working on projects ranked low in task importance, turnover was nearly four times greater than that of groups working on more important tasks.

Job Pressure

On the surface, there is considerable disagreement over whether job pressure is functional or dysfunctional in the R&D environment. A closer examination of research studies, however, reveals that the total absence of job pressure or excessive job pressure is detrimental to both creativity and productivity.

The challenge for the R&D manager is to determine what constitutes reasonable pressure that will result in improved performance. The form the pressure takes is also important. It can, for example, take the form of accepted standards of performance, challenging objectives, time pressures, competition with external organizations, backlog of interesting projects, monthly or quarterly progress reports or level of importance of the task to the organization.

Organizational Levels In the Organization

Many studies of organizations have shown that the fewer the number of levels in the organizational hierarchy, the more efficient and productive the organizations. Too many layers can cause communication problems, delayed decisions and confusion over responsibilities and authority.

If researchers have to go through many organizational layers to obtain approval to work on projects of their own design (an approval structure all too common in government laboratories) then creativity can easily be frustrated. The principal effort and expenditures of time become those of attempting to pass an idea or recommendation for action through channels, defending it at each level. This leaves little time or enthusiasm for developing the idea further (Peters, 1974). As noted earlier, one of the characteristics of a creative scientist is the need to act on an idea as quickly as possible. To have this action slowed down by multiple levels of approval would be very demotivating.

In contrast, having too few approval levels might result in long delays in being able to meet with the required manager because he/she has too much on his/her plate to quickly make a decision (i.e., their span of control is too large).

Rewards for Creativity/Productivity

To encourage creativity and/or productivity, they must be rewarded in a suitable manner when it occurs. Organizational rewards for creative achievement can be divided into two categories:

Intrinsic Rewards

These are rewards which essentially come from within, although their occurrence can be influenced by the organization. The feeling of achievement one gains through successfully solving a challenging problem, or being able to accomplish a difficult task on time is an example of an intrinsic reward. If, however, the organization does not assign or allow an individual to work on a difficult or challenging project, then that source of reward is removed. Assigning projects that allow a person to enhance his or her reputation among colleagues and peers, or to learn new skills or acquire new knowledge, is another form of intrinsic reward. Support for conference attendance is a form of intrinsic reward because it permits research engineers or scientists to present their work before their peers and, if the work is good, gain prestige and recognition from the scientific community. Allowing researchers the freedom to chose their own research projects is a strong form of reward and recognition.

Extrinsic Rewards

These are rewards more commonly associated with working in an organization. They include salary increases, promotions, stock bonuses, and local awards such as plaques and recognition dinners. Increased responsibility and salary, while generally thought of as extrinsic rewards, can also act as intrinsic rewards if they are regarded as a form of recognition by the recipient.

Scientists or research engineers who have a more cosmopolitan orientation will be more motivated by intrinsic rewards, while those with a more local orientation will find extrinsic (external) rewards more appealing.

Amabile and Gryskiewicz (1987) and Pelz and Andrews (1976) found a negative relationship between external motivation and creativity. The latter found a negative correlation between ambition to rise in status within the organization and a scientist's creativity.

However, Pelz and Andrews (1976) found both types of rewards to be very important. There appears to be a paradox over extrinsic rewards. While extrinsic rewards could not be relied on to motivate achievement, when achievement occurred, the extrinsic rewards had to be consistent, and possibly their very provision could stimulate further achievement. Salary is a very powerful source of feedback on how well an employee is performing.

Osbaldeston, Cox and Loveday (1978), in a study of creativity and organization in pharmaceutical R&D, found the following rewards to be most important to the R&D staff:

- the feeling of self-fulfillment in the job;
- recognition for hard work and good performance;
- significant achievement in the job;
- opportunity for independent thought and action;
- working on projects of interest;
- opportunity for personal growth and development;
- future security benefits;
- making a worthwhile contribution to the company;
- opportunity for promotion or career development; and
- having congenial colleagues.

The first six items generally fall into the extrinsic category of rewards.

An item in their study concerned with pay ranked 19th out of 29 possible rewards. These results appear to confirm Herzberg's contention that salary is more important as a maintenance or hygiene factor than as a strong motivator.

Thus rewards and recognition in an R&D-based organization take various forms, all of which can be important depending on the particular needs (goal orientation) of the individual. Scientists or research engineers who wish to build a reputation in the scientific community would want assignments that allow them to make a considerable scientific contribution to their fields and gain the intrinsic rewards of recognition and esteem from scientific colleagues both within and outside their employing organizations. More locally oriented scientists or research engineers who are seeking power and authority to make decisions about the direction of scientific effort in their organizations would seek the more extrinsic rewards of managerial promotion or recognition from senior management.

Gupta and Singhal (1993) suggest that, in innovative companies, people are rewarded for their efforts, not just for results. In this way failure to achieve an R&D project's objectives, despite hard, diligent work is not considered a personal failure of the researchers.

Depres and Hiltrop (1996) in their study of compensation for technical professionals state that, "*knowledge-based compensation and reward designs should focus on challenges inherent in the nature of work while ensuring that monetary rewards and their administration never become an issue among these employees*".

Tolerance of Non-conformity

Another common theme in the lists of factors associated with a work environment that supports creativity is the tolerance of non-conformity. Truly creative people tend to behave unlike the majority of people. They march to a different drummer.

An organization that is overly concerned about how their staff looks and behaves will not be able to support and nourish creative people. Shapero (1985) states that organizations that tolerate non-conformist behaviour from their staff (e.g., no dress code, little rigidity concerning hours of work, etc.) are more likely to enhance the probability of creative performance

General Findings of Studies of Creative R&D Environments

Numerous studies have identified key environmental or work climate factors that encourage or support creativity in R&D laboratories.

Kaplan (1960) considers the following factors important to supporting creativity in an organizational context:

- management being receptive to new ideas;
- existence of suitable pressure to produce (e.g., time pressure, expectations that results are needed, etc.);
- toleration of oddball behaviour by the creative individual;
- freedom to choose problems and change research direction (i.e., autonomy); and
- existence of incentives to encourage creativity.

Steiner (1965) believes that characteristics of a creative organization include the following:

- open channels of communications are maintained;
- contacts with outside sources are encouraged;

- non-specialists are assigned to problems;
- ideas are evaluated on their merits rather than on the status of their originator;
- management encourages experiments with new ideas rather than making "rational" pre-judgements;
- decentralization is practiced;
- much autonomy is allowed professional employees;
- management is tolerant of risk-taking;
- the organization is not run tightly or rigidly;
- participative decision making is encouraged; and
- employees have fun.

Pelz and Andrews (1976) found, in their extensive study of scientists and engineers in organizations, that the situations that seemed to enhance the payoff from creative ability are:

- working on a project or specializing in an area for a relatively short period of time;
- being part of a work team where coordination was not too high and where researchers had the ability to influence important decision makers (i.e., project not completely structured; still room for change); and
- having reasonably good facilities for communicating new ideas to others.

In another study concerned with translation of creative ability into creative performance, the following factors were considered to be important by R&D professionals (Osbaldeston, Cox and Loveday, 1978):

- freedom to follow up on ideas;
- absence of red-tape or bureaucracy;
- atmosphere of openness and trust;
- time for reading, discussion and thought;

- recognition of one's creative contribution;
- working alongside the right people in the right environment;
- rewards for creative work;
- lack of uncertainty or insecurity;
- opportunities for self-development; and
- lack of excessive pressure and work deadlines.

The authors found that, in comparing groups in an R&D laboratory, the group that perceived the greatest satisfaction with environmental climate factors was also viewed as being the most creative.

Another review of the work environment supportive of creativity by a Study Group of the American Industrial Research Institute (IRI, 1969) gave the following as factors that enhanced the probability of creative performance:

- freedom of action for the scientist;
- having well-understood objectives;
- working with productive/creative people;
- having unlimited horizons or challenge;
- recognizing and rewarding creativity; and
- having a liberal publication policy.

In a survey of scientists, the following were named as the "two most important environmental factors" in stimulating creativity:

- freedom to work on areas of greatest interest;
- recognition and appreciation;
- broad contacts with stimulating colleagues;
- encouragement to take risks; and

- tolerating nonconformity.

Gerstenfeld (1970) considers the following to be important factors in developing an organizational climate supportive of creativity:

- the presence of "individual challenge" in the form of opportunity to work on challenging projects (i.e. a known powerful motivator);

- realistic goal setting by R&D management with the R&D manager setting clear and realizable goals with well understood objectives (i.e., removal of role ambiguity which is major source of stress for scientists);

- providing immediate feedback to R&D staff which serves to maintain interest in the accomplishment of objectives (i.e., a powerful incentive for people with a high need to achieve);

- having an effective reward structure and recognition system that meets the individual needs of the researchers;

- openness and allowance of conflicting views are tolerated. The creative person encourages and cultivates a diversity of opinion, especially from colleagues, and relies heavily on exchanging ideas with colleagues both inside and outside the organization. (i.e., produces what Pelz and Andrews calls "dither" which does not allow a group to become insular or complacent);

- having an interdisciplinary approach to problem solving, forming teams made up of people from different disciplines and areas of expertise;

- having the freedom to follow projects from the idea stage to the finished "product" (broadening skills and perspective) but not getting trapped by the product through its product life cycle;

- enhancing the commitment of the researchers to their projects by allowing for greater participation by the research staff in project selection and planning, and through conveying the feeling of project importance;

- maintaining effective communications by not allowing organizational boundaries to become barriers to good communications between R&D personnel and others in the organization; and

- rewarding of original approaches and risk taking and avoiding stress on errorless performance, which Gerstenfeld considers to be a killer of creativity.

Ranftl (1986) in an article on productivity stated that, "*the organizational chemistry required to optimize productivity is synonymous with that required to optimize creativity and innovation*". He described what he considered to be the "seven keys" to achieving high productivity and creativity. In a later article (Wolff, 1992), Ranftl argued that "*leadership is orders of magnitude more important than the other six 'keys'*". The seven keys described in the 1986 article are:

Outstanding Leadership Skills that enable the person to vary his or her leadership style to fit the situation and bring out the best in people and organizations, and to cut through complexity and provide workable solutions to difficult problems.

Skilled Responsible Management who in addition to being technically qualified in their fields, must be respected, people-oriented leaders skilled in the latest techniques of behavioural science and sound business practices.

Organizational and Operational Simplicity, which involves minimal organizational layers consistent with effective operation, minimization of regulations, procedures and red-tape, and delegation of authority as far down the organization as reasonably possible.

Effective Staffing, which involves stressing quality, not quantity, having very high standards for the selection of managers and key personnel, and ensuring a continuous flow of "new blood" into the organization. Weeding out of low performing new hires should be done as early as possible (i.e., within a year).

Challenging Assignments that provide strong motivational fulfillment for the worker.

Objective Planning and Control that help ensure the best possible use of resources, integrates all aspects of a program into an efficient, synchronized effort, provides for future risks and contingencies and preclude continual crisis management. Control systems that measure progress against plans should be simple, objective, timely and cost-effective.

Specialized Management Training to provide managers with the tools and knowledge to improve both personal and corporate productivity.

Westwood and Sekine (1988) believe that a creative environment for R&D personnel consists of:

- a stable working environment (i.e., sustained by steady financial support and a low rate of turnover of staff and management);

- the personal interest of management as evidenced by visibility and the occurrence of one-on-one conversations about the state of technical progress, and whether management's help is needed to overcome administrative roadblocks;

- the establishment of high expectations for performance, together with a feeling of confidence in meeting them; and, most important,

- a clear mutual understanding of the general area in which the staff is supposed to be creative.

The results of a workshop sponsored by the European Industrial Research Management Association (EIRMA) that examined the role of R&D in stimulating creativity and innovation recommended the following actions to encourage creativity (EIRMA, 1994):

- clearly define the company's corporate strategy and R&D strategy to all R&D staff;

- foster creativity by removing fear, a potentially powerful de-motivating element, from the R&D environment;

- put mechanisms in place that allow researchers to pursue, without penalty, a particular idea for which there is no official approval;

- recruit the best people;

- make appropriate continuing training and development available to R&D staff in order to keep their skills and knowledge up-to-date, and to keep them fully motivated; and

- set aside time for creative reflection.

The EIRMA group also felt that it is important to make scientists aware of "technological needs" of client groups.

Johnson (1996) believes that good R&D management is tolerant of failures and near misses, and determined to try again.

R&D Management's Role in Stimulating Creativity

The actions of the R&D manager are critical in encouraging or suppressing creativity in his or her employees. Managerial actions are a major element in the shaping of the work environment.

The orientation and background of senior management can have a major influence on how their organizations view creativity and innovation. Studies by McKinsey and Company (Foster, 1986) indicate that companies led by people with a technical or marketing background outperform those led by financial people by a substantial margin.

Alfred E. Brown, former Director of Scientific Affairs for Celenese (Wolff, 1979) suggest the following actions to stimulate and retain creative talent:

- understanding by management that individuals, not groups, create, and that systems are in place to recognize individual contributions;
- have creative leadership at the top which will facilitate more openness in the sharing of ideas;
- avoid selecting for management positions people who are uncreative, highly structured planner types;
- rotate your creative staff approximately every eighteen months so that they come into contact with other creative people in the organization;
- use the creative people on the toughest problems (i.e., don't frustrate them on routine problems);
- tolerate the oddball behaviour, don't insist on conformity for the sake of appearances; and
- apply time pressure once a research direction or problem-solving approach has been decided upon.

W.G. Sharwell (1981), former V.P. of American Telephone and Telegraph, believes that for innovation to be nurtured on a continuous basis, management must:

- provide stable funding;
- develop and maintain a philosophical commitment to purposeful change; and
- offer employees an environment in which innovation can take place.

Zachary and Krone (1984) noted that, "*an autocratic leadership style is inappropriate for high performance in a research project*". They go on to state that, "*a leader of a high-technology research project will be most effective when utilizing a more egalitarian participative leadership style*".

Albert Shapero (1985), in his studies of creative professionals, recommended the following managerial actions to encourage creativity:

- positive feedback from managers to take more risks, to explore some 'far-out' ideas;

- providing resources to explore new ideas, or turning a blind eye on the 'bootlegging' of an unauthorized project;

- assigning deadlines but allowing freedom on the operating details;

- assigning more than one project at a time to a professional;

- putting together teams of people with different backgrounds, ensure new blood flows into teams; and

- setting up a separate or parallel approval channel to evaluate ideas.

Westwood and Sekine (1988) suggest the following actions to foster creativity in an R&D based organization:

- hire creative people;

- establish a creative environment;

- fund ideas promptly to determine feasibility (i.e., enough resources to conduct the few critical experiments to determine the idea's merit, or otherwise);

- encourage a cross-disciplinary approach to problem solving to bring to bear knowledge from complementary fields;

- encourage the acquisition and exchange of knowledge/information via travel to company operations and to other labs at home and abroad, and by attending conferences;

- provide an up-to-date library, with computer search capability and access to the major data bases, along with a skillful and helpful library staff; and

- provide for frequent seminars by visiting scientists, both distinguished experts and promising beginners.

They also point out that problems assigned to creative people should require an intellectual stretch, because non-critical problems are likely to be treated with disdain.

Ranftl who believes that leadership is a critical factor in encouraging creativity and productivity (Wolff, 1992), states that, "*outstanding leaders create an excitement which everyone wants to be a part to*".

In his studies of stimulating innovative thinking, White (1996) observed that scientists who receive guidance and support from their managers tend to innovate more than those who go

it alone. Thus the oft heard comment of some scientists that "the best management is no management" is not confirmed. White believes that coaching, which walks a thin line between maintaining the researcher's autonomy and guiding the researcher's work to meet organizational objectives, can increase creativity and effectiveness in technical organizations.

Environmental Factors That Inhibit Creativity

In the main, the situations that inhibit creativity are generally the absence of the factors previously identified as promoting creativity.

As noted earlier, having creative ability does not always result in creative performance. Pelz and Andrews (1976) also found this to be the case. Working under conditions that did not call for a creative effort usually had negative consequences for the creative employee.

Osbaldeston et al (1978) found that the R&D staff they studied considered the following to be barriers to creativity:

- workloads;
- time pressures and deadlines;
- management style;
- organizational structure; and
- reward system

In their study of the management of creative people in high-technology research projects, Zachary and Krone (1984) found the following as major de-motivators of research team personnel:

- arbitrary assignment of tasks by the team leader without consultation or negotiation;
- failure to give a team member the opportunity to use his or her expertise, which leads to frustration and reduced feelings of self-worth;
- disproportionate work assignments which leads to feelings of being used;
- failure of others in the team to listen to or make an effort to understand a member's ideas; and
- lack of clarity concerning project goals, the framework for accomplishing them, and the roles of the team members can lead to conflict and high levels of individual stress.

Shapero (1985) suggests the following will effectively kill creativity in an individual or an organization:

- discourage and penalize risk-taking;
- discourage and ridicule new ideas;
- reject and discourage attempts to try unusual methods;
- make sure all communications follow formal organizational lines and all employees cover themselves;
- discourage reading and communications with people outside the immediate organization
- discourage nonconformity of any kind;
- discourage joking and humour;
- provide no recognition for creative ideas; and
- provide no resources to follow through with creative ideas.

Amabile and Gryskiewicz (1987) found that the most frequently-mentioned environmental factor associated with low creativity events was constraint, defined as, "*a lack of freedom in deciding what to do or how to do one's work*". Other factors associated with low creativity were:

- organizational indifference to the work;
- a lack of faith in the project;
- a general apathy or complacency toward research;
- lack of sufficient time and resources assigned to a project (deadlines set arbitrarily);
- inappropriate competition between groups or individuals who should have been cooperating.
- too much emphasis on external rewards, or unfair distribution of rewards;
- overly formal and complex organizational structures and communication channels;
- unrealistic expectations;

- general concern about criticism and external evaluation of work;
- overemphasis on the status quo by senior management; and
- avoidance of controversial ideas, and not wanting to take risks.

Ranftl (Wolff, 1992) adds the following to this list of negative factors:

- over-inflated and overly complex organizational structures;
- ineffective technology transfer and exchange;
- lack of a equitable parallel promotion ladder; and
- insufficient attention to employee morale and motivation (particularly when all too many organizations have taken "a revolutionary, meat-axe approach to downsizing R&D in which both productivity and creativity suffer")

R&D PRODUCTIVITY

While R&D productivity is not synonymous with creativity, there is a body of evidence that highly creative scientists are also very productive. This occurs because the operational definition of creativity used by government or business organizations usually includes the concept of usefulness.

R&D productivity cannot be measured precisely, and may never be, because of the variation in outputs that can occur from project to project, and the variation in complexity of different R&D projects. No base exists from which a particular R&D output can be measured. Compounding the measurement problem is the fact that the impact of research results may not be recognized at the time they are developed. It is not uncommon, for example, for people to receive a Nobel Prize in science many years after their initial discovery.

Both quantitative and qualitative criteria are used in attempting to measure R&D productivity. These include papers published in learned journals, papers published in "trade" reports, internal reports, patents disclosed, conference/management presentations, citation index references, peer assessment, scientific society awards received, quality and usefulness of ideas generated, profits generated per R&D dollar spent, supervisor assessment and number of projects completed on time and within budget.

Impact of Culture or Work Climate on Productivity

As in the case of creativity, work climate or culture can have a major impact on R&D productivity.

Hurley (1995) conducted a major study of the impact of internal receptivity to new ideas and innovation (described as innovativeness) in 38 groups in a large American government R&D organization and resultant innovative productivity as measured by the number of science and technical awards. He found that the more the group's culture was characterized by innovativeness, the greater was the level of innovative output of the group. He also found that the more the group's culture emphasized participative and open decision making, and people and career development, the higher was the group's score on innovativeness.

Effect of Job Satisfaction on Productivity

Individuals are satisfied with their jobs to the extent that their work provides them with what they desire in terms of financial and psychological needs, and perform effectively in their jobs to the extent that their effective performance leads to the attainment of what they desire.

A study of the relationship between productivity and job satisfaction in a government R&D facility showed that R&D personnel with the highest job satisfaction are the most productive, as measured by the number of papers published, patent disclosures and presentations (Vincent and Mirakhor, 1972). From their findings, the authors concluded that the effective utilization of scientists and engineers was dependent on a work environment that successfully produces high job satisfaction. They found the following factors contributed to high job satisfaction:

- salary;
- challenge of assignments;
- nature of assignments (i.e., variety versus monotonous);
- opportunity to use initiative; and
- geographical location.

The authors noted that while salary and geographical location were not under the direct control of local management, job assignment was, and should be used to increase job satisfaction. They further argue that both intrinsic and extrinsic rewards should be used to encourage productivity.

Managerial Factors That Encourage Productivity

The following information is taken from the Hughes Aircraft study on R&D productivity (Ranftl, 1978).

Study findings clearly stress that the approaches taken and techniques practiced by management have a tremendous potential for either stimulating or depressing productivity. It is equally evident that any given management approach or technique cannot be expected to stimulate all employees or apply to all situations in the same way. Therefore, managers who wish to improve productivity must exercise acute awareness and perception, be continually picking up and interpreting cues, and tailor their managerial style to meet the needs of the situation.

To supervise effectively, managers must exhibit a genuine interest in employees; interest supported by attention to and concern for them and their work. When employees feel that their abilities are respected and that proper recognition and rewards are given for their efforts, they will normally perform effectively and measure up to the expectations of management. Only when management gives employees proper attention will employees give management' s concerns proper attention.

According to participants in the R&D productivity study, managers with the most productive employees have a unique mix of technical competence, people-oriented leadership skills, and sound administrative ability. In the past, R&D managers were often able to get by on technical competence alone; today's R&D environment with global competition, demands much broader capabilities.

The study participants identified the following objectives for R&D managers to increase productivity:

- establish high performance standards and promote personnel and product excellence;
- determine what objectives to pursue, based on a thorough knowledge of the technology market or client needs, actions of competitors, and available resources;
- optimize the use of all available resources; be alert for unused and underutilized resources, and in particular strive for total involvement of the entire work force;
- develop a sense of entrepreneurship throughout the organization, ensuring that everyone is performance-oriented;
- delegate authority, responsibility, decision making, control, and accountability as far down the organization as is practical;
- manage time effectively by setting priorities and deadlines, and by stopping nonproductive efforts as soon as possible;

- invest in future technology through sound basic and applied R&D programs;
- be open-minded and imaginative, quick to see the potential of new concepts and ideas;
- encourage technological innovation and the use of the latest technical aids;
- keep the organization "tuned up"; always search for more productive ways of doing things;
- be alert for, and correct, counterproductive factors within the organization;
- apply work elimination, simplification, and standardization techniques wherever appropriate;
- strive for preventive rather than corrective action;
- encourage an effective working relationship between R&D and all other related organization and client activities;
- ensure that no individual or facet of the organization gets shortchanged or over emphasized;
- minimize organization politics and gamesmanship; avoid the connotation of "insiders" and "outsiders";
- encourage healthy competition between groups or with other organizations; but minimize competition within any one particular R&D project group;
- maintain effective, equitable compensation and promotion policies;
- regularly review the need and justification for overhead and capital expenditures, keeping both in line with efficient operating practice; and
- critique past performance to learn from both successes and failures of earlier R&D efforts.

Again, many of these managerial factors or actions will have a direct effect on the incidence of creativity through their considerable impact on the motivation of the research staff.

In order to increase R&D productivity, two American Forest Service Experiment Stations adopted, as part of a pilot test, the following managerial changes (Lewis and DeLaney, 1991):

- increased use of interdisciplinary teams;

- managers encouraged new ideas, and reduced the fear of being penalized for trying new approaches;
- abolished limits on the number of scientists attending a particular scientific meeting;
- research scientists were relieved of administrative burdens and allowed to concentrate on scientific tasks; and
- funds were made available to pursue new ideas or to allow new innovations to be pursued in a timely way.

In his review of why some R&D organizations are more productive than others, Bean (1995) found the following factors associated with higher productivity:

- organizations conducted strategic basic research;
- they avoided sacrificing basic research activities for technical service activities in order to maintain their long-term competitiveness;
- had longer term R&D planning horizons (4-6 years) and review cycles (2-3 years);
- R&D executives had high expectations regarding the potential contribution of R&D to meet corporate goals (e.g. one being the competitive position of the firm); and
- a willingness to look outside the firm for technology; rejected the "NIH" syndrome.

Organizational Factors That Inhibit Productivity

Lewis and DeLaney (1991) describe some of the problems that inhibit government research organizations in being effective and productive:

- poor public perception of goals or mission;
- inflexible program development process;
- fragmentation of broad problems along functional lines;
- inflexible program-funding guidelines;
- inability to acquire funds to capitalize on emerging research opportunities;

- excessive paperwork and administrative burdens that distract scientists from the primary function of research; and

- inflexible recruitment and hiring practices that make it difficult to compete for the best people.

Managerial Factors That Can Suppress Productivity

In an extensive study of R&D productivity by the Hughes Aircraft Company, Ranftl (1978) found that study participants considered the following factors most likely to reduce productivity within R&D organizations:

- ineffective planning, direction and control;

- overinflated organizational structures;

- insufficient management attention to productivity, and to the identification and elimination of counterproductive factors within the organization;

- overstaffing;

- poor internal communications;

- inadequate technology exchange;

- insufficient or ineffective investment in independent R&D efforts;

- poor psychological work environment;

- lack of a people-orientation by management, insufficient attention to employee motivation;

- misemployment;

- ineffective structuring of assignments;

- lack of effective performance appraisal and feedback;

- insufficient attention to low performers;

- technological obsolescence;

- ineffective reward systems which inadequately correlate individual productivity and compensation;
- lack of equitable parallel managerial and technical promotion ladders;
- lack of equity in operations;
- ineffective customer/client interface;
- ineffective engineering/production interface;
- ineffective subcontractor/supplier interface and control;
- operational over-complexity, restrictive procedures and red-tape;
- excessive organizational politics and gamesmanship;
- ineffective management development; and
- inadequate investment in, and lack of proper maintenance of, capital facilities.

From the earlier section on creativity, it is clear that many of these factors would also have a deleterious effect on creativity.

ANALYSIS AND SUMMARY

FACTORS OR ACTIONS THAT SUPPORT CREATIVITY

The literature on creativity is quite consistent over time in its agreement on the factors or actions needed to encourage creativity in an R&D environment.

Senior Management Support

It will be difficult, if not impossible, to develop a work environment that supports creativity or productivity if senior management does not with it. Many of the actions outlined below that are needed to encourage creativity must be sanctioned by senior management. Without their full and active support, lower level managers will be reluctant, for example, to take the necessary steps to remove any organizational barriers that impede creativity or productivity.

Hire Creative People

The first and foremost action is to hire people who display the characteristics associated with creative employees, once it has been determined that creative people are really needed in the organization.

Among the key characteristics or attributes of creative research engineers and scientists are:

- internally motivated (self-motivated), don't respond to the kinds of incentives that motivate others;
- intellectually curious, with a diversity of interests;
- willingness to try out new approaches or ideas, and to take risks;
- able to see connections between blocks of seemingly unrelated information and put them together in unique ways in order to solve a problem;
- attracted by the challenge of a problem or situation;
- non-conformist, have unusual work patterns or behaviour, have little reverence for authority, intolerant of bureaucracy; and
- able to continue working on a project or problem to which they are committed despite counter-influences, opposition or discouragement.

Employment Contract as a Long-term Commitment

Creative scientists and research engineers require relatively long-term stability in their work environment. Despite the latest management fad concerning the "new employment contract", studies such as those of Abraham Maslow show that for people to operate at their creative best, they must have their security needs satisfied (Clarke, 1997). This will not occur if the employee is under a constant threat of unemployment.

As many management authors point out, reducing fear in the R&D environment, reducing uncertainty or insecurity, providing a stable working environment with a low rate of staff turnover, and providing stable funding are key factors in encouraging creativity and productivity (Osbaldeston et al, 1978; Sharwell, 1981; Westwood and Sekine, 1988; Ranftl, in Wolff, 1992; and EIRMA Workshop, 1994).

The degree of job involvement, a factor associated with creativity, will also be negatively affected by short-term employment practices.

Allow for Freedom and Autonomy in Decisions About Work

This factor stands out above all others as being critical to the creative process with scientists and research engineers.

The main form of freedom or autonomy mentioned in the literature is freedom to determine how a project or problem will be tackled. Some organizations go as far as allowing researchers to select the project they will work on (e.g., 3M's 15% of time/resources spent on personal projects).

Other forms of freedom mentioned in the literature are freedom to follow up on ideas, freedom to change research direction when necessary, freedom to work on areas of greatest interest, freedom to follow projects from the idea stage to the "finished" product, and freedom to pursue, without penalty, ideas that do not have official approval (Kaplan, 1960; Steiner, 1965; Gerstenfeld, 1970; Osbaldeston et al, 1978; Shapero, 1985; EIRMA Workshop, 1994) .

Total freedom, however, is not conducive to useful creativity. Thus most authors recommend that freedom/autonomy be generally confined to the determination of approaches to solve a problem, rather than in setting the R&D agenda (Amabile and Gryskiewicz, 1987; Pelz and Andrews, 1976).

Provide Challenging, Interesting Project Assignments

The assignment of research projects is a critical managerial tool for encouraging creative and productive output from research scientists and engineers.

Challenging, interesting assignments are noted by many management authors as being a key factor in supporting creativity and productivity in an R&D environment Vincent and Mirakhor, 1972; Osbaldeston et al, 1978; IRI Study Group, 1969; Gerstenfeld, 1970; Wolff, 1979; Ranftl, 1986; Bean, 1995). For this reason, creative personnel would like the freedom to select their own projects.

Challenging, interesting assignments, when successfully completed, allow researchers to gain the respect and recognition from their peers, and provide for their needs to experience achievement and self-fulfillment on the job. Uninteresting, unchallenging assignments do not allow for need satisfaction and can be a major source of de-motivation.

The importance of the research project to either the organization, or to the advancement of science or engineering is a major factor in ensuring the involvement of creative personnel (Kaplan, 1960). This, in turn, has been noted as a factor in productive R&D organizations (Bean, 1995). The assignment of a low-importance project to a creative person will not result in creativity or productivity.

Work assignments can also play a major role in preventing technological obsolescence among researchers. Challenging projects that demand that researchers must learn new techniques or acquire new knowledge provide opportunities for growth and self-development.

Many management authors also point out that having clear goals or objectives on work assignments is important to creativity and productivity (IRI Study Group, 1969; Gerstenfeld, 1970; Zachary and Krone, 1984; Westwood and Sekine, 1988; EIRMA Workshop, 1994).

Provide Adequate Resources

To encourage creativity and productivity, the researchers must be provided with adequate resources in terms of personnel, equipment, facilities and time.

It is extremely frustrating to a professional to be give a challenging, interesting assignment, but not the necessary resources to complete it in an effective manner.

Stable financial support is a major factor in sustaining the researcher's committment and enthusiasm for a project and in encouraging creativity (Sharwell, 1981; Westwood and Sekine, 1988). Resources should also be available to follow up on unplanned ideas as they evolve during a project (Shapero, 1985; Lewis and DeLaney, 1991).

Creative workers must be provided with sufficient time for reading, discussion and thought and creative reflection (Osbaldeston et al, 1978; EIRMA, 1994).

While pressure in the form of deadlines is thought to encourage creativity, the deadline should be set in consultation with the staff, otherwise it is counterproductive (Osbaldeston et al, 1978; Amabile and Gryskiewicz, 1987; Wolff, 1979)

More time can be made available for creative people to conduct their research by reducing their administrative burdens (Lewis and Delaney, 1991).

Encourage Risk Taking

Risks will be taken only if it is safe to take them. If an organization severely penalizes employees for taking risks and failing, then no risks will be taken. If success in trying something new is not rewarded then employees will play it safe and stick with the status quo, no matter how ineffective present practice is. This is the situation in many government organizations were the emphasis is on "not rocking the boat".

Encouragement to take risks and try something new, and to be open to new ideas is noted by many management authors as an important factor in encouraging creativity (Steiner, 1965; IRI Study Group, 1969; Gerstenfeld, 1970; Shapero, 1985; EIRMA, 1994; Amabile and Gryskiewicz, 1987; Ranftl, 1978; Lewis and Delaney, 1991; Johnson, 1996).

Ensure a Responsive and Equitable Reward and Recognition System

Although creative scientists and research engineers are generally self-motivated, it is important that an organization has in place a system of rewards and recognition that reinforces the creative behaviour of its research staff. This is considered to be a major factor by most of the authors reviewed.

Intrinsic (internal) rewards (psychological need satisfaction) are seen to be associated more with creativity than extrinsic rewards such as salary or promotion.. Thus management should ensure that its actions provide for intrinsic rewards or forms of recognition.

Among the intrinsic rewards sought by R&D staff are:

- the feeling of self-fulfillment that comes from completing a difficult task;
- recognition for hard work and good performance from peers and colleagues;
- experiencing significant achievement for a job well-done;
- having the opportunity to grow and develop as a professional;
- having the authority to make decisions about their work;
- appreciation of their creative contributions and ideas; and
- receiving constructive feedback on their progress.

Extrinsic rewards, which are sought out by researchers who look to their employer for recognition and reward, must be provided in a fair and equitable manner, otherwise de-motivation and conflict can occur.

Lack of a dual promotion ladder for researchers has been associated with low creativity (Wolff, 1992).

Employ Managers who Can Manage in a Consultative Style

The immediate supervisor is the most important environmental influence in the work of the research engineer and scientist. Because of the many special characteristics of creative personnel, they must be managed in a way that makes use of those characteristics.

The major factor associated with a manager is his or her style of management. It is vital that the manager of creative personnel has a consultative (or participative) style of management (Zachary and Krone, 1984). As freedom and autonomy have been identified as critical factors in promoting creativity, the manager must be comfortable in allowing the researcher considerable latitude in the conduct of the research.

As many of the management authors state, the effective R&D manager must combine technical skills and know-how with people-oriented leadership skills that enable him or her to bring the best out in their research staff (Ranftl, 1986: White, 1996).

An autocratic manager would be unable to share decision making and authority with employees and would want to micro-manage to the point where individual initiative and creativity would be stifled (Pelz and Andrew, 1976).

Encourage Effective, Timely Communication

Information is the life-blood of a research organization. The work environment should encourage communication among the research staff and others in the organization, as well as among the research staff and knowledgeable researchers elsewhere.

Internal communication should not be tied to the organization's authority structure. Researchers should be free to contact anyone in the organization regardless of rank or organizational unit. To facilitate this, there should be an atmosphere of openness and trust (Osbaldeston et al, 1978; Gerstenfeld, 1970; Shapero, 1985; Amabile and Gryskiewicz, 1987).

External information acquisition should be facilitated by visits to other laboratories, conference attendance, a good library and computer facilites, visits by world experts, and a rejection of the Not Invented Here Syndrome (Shapero, 1985; Westwood and Sekine, 1988; Lewis and DeLaney, 1991; Wolff, 1992 Bean, 1995).

There should also be a tolerance for conflict; an organization that suppresses conflict, suppresses creativity. Researchers should be free to raise controversial ideas. (Gerstenfeld, 1970).

Tolerate Non-conformity

Organizations that wish to encourage creativity must be tolerant of individual work styles. Creative people do not fit the "9 to 5" mold. They may consider organizational norms for dress as irrelevant.

Many management authors who study creativity in the R&D setting advise that organizations should, within reason, tolerate "oddball" behaviour from their creative personnel (Kaplan, 1960; IRI Study Group, 1969; Wolff, 1979; Shapero, 1985) . To do otherwise, will engender feelings of frustration in the creative worker who will view pressures to conform as unwarranted intrusion on his or her autonomy and a lack of respect for their creative contribution to the organization (i.e., the organization is more concerned about how they look or behave, rather than their creative output).

FACTORS OR ACTIONS THAT DEPRESS CREATIVITY

As noted earlier, the conditions that inhibit or depress creativity are generally the absence of the factors that have been identified as those that encourage creativity.

The unsupportive actions or factors that depress creativity (and productivity) can be grouped as follows:

Inappropriate Managerial Actions

Management having an autocratic management style is a major suppresser of creativity within an R&D organization. The following are some of the inappropriate managerial actions that will discourage creativity:

- lack of freedom to choose R&D projects, or at least to determine how the research should be conducted;
- setting of unrealistic workloads, and deadlines;
- assignment of unchallenging and/or uninteresting work;
- setting unclear goals and objectives;
- discouraging and penalizing risk-taking;

- restricting communications and the flow of technical information; and
- lack of consultation with the scientific staff on decisions concerning them.

Lack of Appropriate Rewards or Recognition for Creativity

Creativity and productivity must be constantly and consistently encouraged. Uncreative organizations:

- provide little or no recognize for creative work;
- lack enthusiasm for the work of R&D personnel;
- place too much emphasis on external monetary rewards; and
- lack an equitable parallel promotion ladder for scientific personnel.

Overall Negative Work Environment

The following environmental factors result in depressed creativity:

- many managerial levels involved in decision-making;
- confining all communications to the formal organizational structure;
- general discouragement of novel approaches to problem solving (i.e., overemphasis on the status quo);
- resources tightly controlled with no "spare" built in to support unexpected ideas; and
- overly formal organizatonal structure.

FACTORS OR ACTIONS THAT SUPPORT R&D PRODUCTIVITY

Many of the factors or actions that promote creativity also promote productivity. As before, senior management must want to promote productivity and take actions to ensure that it occurs.

Among the key actions or factors that encourage R&D productivity are:

- the employment of competent R&D managers and staff;

- managerial interest in, and respect for their employees;
- establishment of high performance standards;
- constantly striving to improve the operation of the organization;
- adequate delegation of responsibility and authority;
- effective time management;
- investment in the future through funding of strategic basic research activities;
- being receptive to new ideas and approaches;
- minimization of organizational politics;
- encouragement of healthy competition between groups;
- existence of equitable compensation and promotion policies;
- examination of past performance, good and bad, to learn how to improve;
- allowing research staff to focus their energies on research;
- existence of resources to follow up on new ideas, and
- senior management's having high expectations of the contribution R&D will make in meeting corporate goals.

FACTORS OR ACTIONS THAT INHIBIT R&D PRODUCTIVITY

Among the key factors or actions that reduce productivity are:

- ineffective planning, direction and control;
- inflexible program funding guidelines;
- excessive administrative burdens that distract the research personnel from conducting research;
- inability to recruit and hire the very best people;

- overinflated organizational structures;
- poor internal communications;
- inadequate investments in independent R&D efforts;
- lack of a people-orientation by management;
- technological obsolescence;
- ineffective reward systems that do not link compensation and recognition to productivity and performance;
- lack of dual promotion ladder for scientific personnel; and
- ineffective management development.

These negative factors are also major sources of inhibition for creativity.

CONCLUSION

It is clear from this review of the literature, that organizational environment, of which managerial style is an important element, is a critical intervening variable between a potentially creative, productive scientist or engineer and creative, productive performance.

Although creativity does not lend itself to planning, developing the organizational context in which creativity and high productivity can occur can be planned. Creativity is like a seed, the ground has to be prepared to receive it, otherwise it will germinate and quickly die for lack of supportive nutrients.

Managerial actions have a considerable effect on the emergence of creativity. If an organization's management requires that everyone conforms to unwise, restrictive policies, if the tasks assigned are uninteresting and lack challenge, and if there are no opportunities for the research staff to learn new skills or gain new knowledge to keep them current, then in all probability, creativity will be stifled.

Management can take concrete actions to establish a work environment that increases the probability of creative behaviour among its scientific staff, assuming that the organization has hired potentially creative people in the first place.

All too often, however, organizations claim to want a creative effort or to increase productivity, but are unwilling to remove the barriers to creativity or to eliminate unproductive policies or procedures in the work place. This resistance to making needed changes is especially evident in government laboratories with their general rules and policies designed to cover all manner of organizational activities, the mundane and repetitive, as well as the creative and innovative.

Lack of change in the face of the clear need for improvement only increases the frustration and cynicism of the scientific staff, who, in turn, become even more alienated and unmotivated. This results in reduced creativity and productivity.

Marvin Johnson (1996) sums up the situation quite well, *"If and when an organization becomes risk averse, satisfied with past accomplishments, and not anxious to compete, it will soon cease being inventive and eventually fail; it is happening around us".*

REFERENCES

Amabile, Teresa M. and Gryskiewicz, Stanley S., "Creativity in the R&D Laboratory", Technical Report No. 30, Center for Creative Leadership, P.O. Box 26300, Greensboro, NC, 2748-6300, May, 1987

Andrews, F.M., "Social and Psychological Factors which Influence the Creative Process" in Perspectives in Creativity, edited by I.A. Taylor and J.W. Getzels, Chicago, IL: Aldine, 1975

Bailyn, L., "Autonomy in the Industrial R&D Lab", Working Paper #1592-84, Albert P. Sloan School of Manaement, M.I.T., 1984

Bean, Alden S., "Why Some R&D Organizations Are More Productive than Others", Research-Technology Management, Vol. 38, No. 1, January-February, 1995, pp. 25-29

Clarke, Thomas E., "Danger - Management Myth Ahead", Research-Technology Management, Vol. 40, No. 1, January-February, 1997

Clarke, Thomas E., "The Work Environment and Mental Health", Studies in Personnel Psychology, Vol. 3, No. 2, October, 1971, pp. 83-96

Clarke, Thomas E. and Reavley, Jean, "Science and Technology Management Bibliography - 2001", Nanaimo, B.C.: Stargate Consultants Limited, 2001 [Now 1954-2010, http://www.tomeclarke.ca]

Depres, Charles and Hiltrop, Jean-Marie, "Compensation for Technical Professionals in the Knowledge Age", Research-Technology Management, Vol. 39, No. 5, September-October, 1996, pp. 48-56

EIRMA, "Stimulating Creativity and Innovation", Research-Technology Management, Vol. 37, No. 2, March-April, 1994, p. 13

Ekvall, G., "Climate, Structure, and Innovativeness of Organizations", (Report 1), Stockholm, Sweden: The Swedish Council for Management and Organizational Behavior, 1983

Foster, R.M., "Innovation: The Attacker's Advantage", New York: Summit, 1986, p. 242

Gerstenfeld, Arthur, "Organizational Climate for Creativity", in Effective Management of Research and Development, (Ch. 5), Reading, MA: Addison-Wesley, 1970, pp. 55-67

Gupta, Ashok K. and Singhal, Arvind, "Managing Human Resources for Innovation and Creativity", Research-Technology Management, Vol. 36, No. 3, May-June, 1993, pp. 41-

Hurley, Robert F., "Group Culture and Its Effect on Innovative Productivity", Journal of Engineering and Technology Management, Vol. 12, Nos. 1/2, July, 1995, pp. 57-75

IRI Study Group, "Motivation, Incentives, and Rewards for R&D Personnel", Research Management, Vol. 12, No. 3, May, 1969, pp. 169-171

Isenson, R.S., "Allowed Degrees and Type of Intellectual Freedom in Research and Development", IEEE Transactions on Engineering Management, Vol. EM-12, No. 3, September, 1965, pp. 113-115

Johnson, Marvin M., "Finding Creativity in a Technical Organization", Research-Technology Management, Vol. 39, No. 5, September-October, 1996, pp. 9-11

Kaplan, Norman, "Some Organizational Factors Affecting Creativity", IRE Transactions on Engineering Management, Vol. EM-7, No. 1, March, 1960, pp. 24-30

Lewis, Robert and DeLaney, William F., "Promoting Innovation and Creativity", Research-Technology Management, Vol. 34, No. 3, May-June, 1991, pp. 21-25

McPherson, J.H., "A Proposal for Establishing Ultimate Criteria for Measuring Creative Output", in Scientific Creativity: Its Recognition and Development, C. Taylor and F. Barron, eds., New York: Wiley, 1963, pp. 2-29

Osbaldeston, M.D., Cox, J.S.G. and Loveday, D.E.E., "Creativity and Organization in Pharmaceuticals R&D", R&D Management, Vol. 8, No. 3, 1978, pp. 165-175

Pelz, D.C. and Andrews, F.M., "Freedom" in Scientists in Organizations, Ch. 2, New York: Wiley, 1976, pp. 8-34

Perry, Tekla S., "Managed Chaos Allows More Creativity", Research-Technology Management, Vol. 38, No. 5, September-October, 1995, pp. 14-17

Peters, E.B., "Overcoming Organizational Constraints to Creativity and Innovation", Research Management, Vol. 17, No. 3, May, 1974, pp. 29-33

Ranftl, Robert M., "R&D Productivity", Study Report, Second edition, Culver City, CA: Hughes Aircraft Company, 1978

Ranftl, Robert M., "Seven Keys to High Productivity", Research Management, Vol. 29, No. 5, September-October, 1986, pp. 11-18

Shapero, Albert, "Managing Creative Professionals", Research Management, Vol. 28, No. 2, March-April, 1985, pp. 23-28

Sharwell, W.G., "A Prescription for Innovation", Research Management, Vol. 29, No. 1, January, 1981, pp. 6-7

Smeltz, Wayne and Cross, Barrington, "Toward a Profile of the Creative R&D Professional", IEEE Transactions on Engineering Management, Vol. EM-31, No. 1, February, 1984, pp. 22-25

Steiner, G.A., "The Creative Organization", Chicago, IL: University of Chicago Press, 1965

Vincent, H.F. and Mirakhor, A., "Relationship Between Productivity, Satisfaction, Ability, Age, and Salary in a Military R&D Organization", IEEE Transactions on Engineering Management, Vol. EM-19, No. 2, May, 1972, pp. 45-53

Westwood, Albert R.C. and Sekine, Yukiko, "Fostering Creativity and Innovation in an Industrial R&D Laboratory", Research-Technology Management, Vol. 31, No. 4, July-August, 1988, pp. 16-20

White, Daniel, "Stimulating Innovative Thinking", Research-Technology Management, Vol. 39, No. 5, September-October, 1996, pp. 31-35

Wolff, Michael, "R&D Productivity Revisited", Research-Technology Management, Vol. 35, No. 3, May-June, 1992, pp. 12-14

Wolff, Michael, "How to Find - And Keep -- Creative People", Research Management, Vol. , No. 9, September, 1979, pp. 43-45

Zachary, William B. and Krone, Robert M., "Managing Creative Individuals in High-Technology Research Projects", IEEE Transactions on Engineering Management, Vol. EM-31, No. 1, February, 1984, pp. 37-40