Lethality: Dependence on Developmental Rate in X-Irradiated Pupae of *Tribolium*

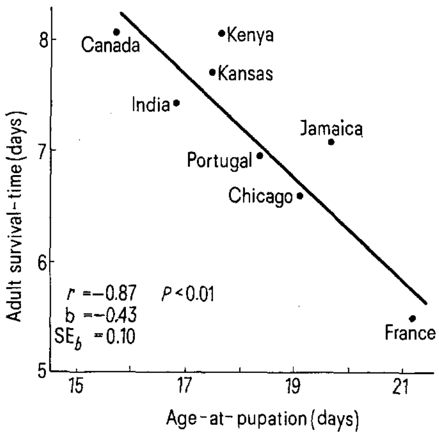
The relative adaptiveness of a population to its current environment may be termed its short term fitness[1]. Developmental rate and productivity are two intrinsic factors contributing to such fitness. High levels of irradiation, on the other hand, will limit population growth and therefore affect its short term fitness. An understanding of the genetic and phenotypic relationship between the response (lethality) of a species to X-irradiation and other fitness components (developmental rate and productivity) can be achieved by 2 approaches: 1. a detailed examination of the relationship between the fitness components and the response within each population will indicate the specific relationship as a consequence of the natural past selection pressure[2], and 2. by computing the correlation coefficient between the phenotypic values of any 2 fitness components for all the different populations after a given exposure to irradiation. If there is a sufficiently large number of individuals for all populations with wide genetic difference, then this correlation will reflect a 'genetic correlation' in a broad sense[3]. Such inter-population correlation is dealt with in this paper.

Eight laboratory populations of *Tribolium castaneum*, identified by their geographic origin, were used in this investigation. Eggs were collected from a variable number of parents (Table I), and kept at 33 °C and 70% relative humidity in standard medium. Pupae were separated daily, and X-irradiated (10 kr in 20 min at 300 kV and 20 mA with unfiltered HVL 5 mm A1 and 15.5 cm TSD) next day, during the entire period of pupation. Dead adults were recorded in 2-day intervals after 5 days of emergence.

The 2 fitness measurements are presented in Table I with the response to X-irradiation in terms of lethality (measured as percent adult emergence and adult survival-time). Table II shows that most of the interpopulation correlations are non-significant, indicating that different genetic mechanisms may be responsible for change in fitness[4].

The only significant correlation is that between the age-at-pupation and adult survival-time. The regression analysis indicates a highly significant negative relationship between both traits (Figure), where the increase in age-at-pupation by one day results in a decrease in adult survival-time by 0.43 ± 0.1 day.

If life expectancy in *Tribolium* is as it is in *Drosophila*[5,6] then it is possible to assume that the variation between the adult survival-time after X-irradiation reflects variation between the life expectancy among these populations. This means that the increase in pupation time is



Inter-population relationship between age-at-pupation and adult survival-time after X-irradiation of 2-day-old pupae of 8 populations of *Tribolium castaneum*.

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Table I. Parameters of fitness components before X-irradiation and the response after X-irradiation of 2-day-old pupae of 8 populations of *Tribolium castaneum*

Population	No. of parents	Fitness measurements			Response after X-irradiation	
		No. of pupae produced		Age at pupation (days) ± SE	Percent adult emergence[a]	Survival-time (days) ± SE[b]
		Total	Per parent			
Kenya	90	737	8.19	17.67 ± 0.06	47.53	8.05 ± 0.13 d
Jamaica	84	740	8.81	19.63 ± 0.07	37.79	7.08 ± 0.13 ab
India	79	753	9.53	16.70 ± 0.07	31.77	7.41 ± 0.12 bc
Chicago	79	729	9.23	19.07 ± 0.05	26.43	6.58 ± 0.15 a
Portugal	95	979	10.31	18.23 ± 0.06	23.34	6.95 ± 0.13 a
Kansas	100	705	7.05	17.47 ± 0.06	18.83	7.73 ± 0.27 cd
France	100	390	3.90	21.14 ± 0.06	15.26	5.48 ± 0.09
Canada	92	560	6.09	15.62 ± 0.04	6.80	8.03 ± 0.36 cd
Total	719	5593	7.78	18.15 ± 0.03	28.48	7.25 ± 0.06

Age-at-pupation and the response are means based on the daily number of pupae produced during the entire period of pupation. [a] Control was over 97% for all populations. [b] Any 2 populations having the same letter are not significantly different at $P < 0.05$ by Student-Newman-Keuls test.

associated with the decrease in survival-time in *T. castaneum* (Figure). These results seem to contradict the conclusion arrived at in *Drosophila* by LINTS and LINTS[7]; *viz.*, that 'a prolongation or a shortening of the duration of development results in an increase or in a decrease in the speed of the aging process'. This apparent contradiction may be due to the difficulty of comparing 'normal' life span with life span shortening after irradiation which may be due to lethal radiation syndrome not related to aging[8]. To compare lethality and life span shortening a lower radiation dose should be used. However, the present results indicate that lethality of a species as measured by survival-time is under the control of a genetic system. Most likely such a system has evolved as a result of the forces tending to prolong life and the environmental hazards tending to curtail it[9,10]. Other investigators have also recorded the effect of particular chromosomes on the variability of longevity in *Drosophila*[11].

In some of the populations (Table I) survival-time was found to be positively associated with survival rate (e.g., Kenya and France). This observation suggests the possibility of correlation between the 2 measurements of lethality, i.e., survival rate and survival-time after irradiation. However, inter-population correlation ($r = 0.16$, $P = 0.1$) indicates that this is not the case. Recently, BLAIR and BAXTER[6] have suggested that the 2 types of injury are mutually independent. The lethal injury resulting in reducing survival rate is mainly cytoplasmic, the damage is of a chemical nature and repairable; whereas reduction in survival-time is due to nuclear injury (chromosomal), which in these cases is not repairable. A theory based on loss of cellular function was also suggested by GARTNER[12] to explain radiation induced life span shortening.

Table II. Inter-population correlation between fitness parameter and response after X-irradiation (Table I) in *Tribolium castaneum*

Traits	Survival-time (days)	Age-at-pupation (days)	Productivity (%)
Adult emergence (%)[a]	0.16	0.18	0.57
Survival-time	—	−0.87[b]	0.31
Age-at-pupation	—	—	−0.25

[a] After angular transformation. [b] Significant at $P = 0.01$.

Résumé. Après irradiation des pupes âgées de 2 jours, le temps de survie des adultes de *Tribolium castaneum* décroit avec l'âge de la pupation. Cette corrélation génétique négative indique que la vitesse de développement contrôle la létalité qui est maintenue à une valeur intermédiaire, peut-être à cause d'un jeu de forces opposées qui, elles, tendent à allonger ou à raccourcir le temps de survie.

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Intestinal Motility Increased by Tetrodotoxin, Lidocaine, and Procaine

The existence of intrinsic intestinal inhibitory nervous mechanisms has been demonstrated[1]; but the extent to which intestinal motility is a result of myogenic activity and modified by intrinsic excitatory and inhibitory nervous factors is uncertain. An increased mechanical activity in cat intestinal circular muscle has been shown in vitro upon blockade of neuronal discharge in Auerbach's plexus and the possibility of a tonic inhibitory influence on circular muscle activity via intrinsic neurogenic elements has been postulated[2].

This preliminary report describes observations in anesthetized cats where intraarterial injections of the nerve blocking drugs tetrodotoxin, lidocaine, and procaine to the extrinsically denervated intestinal vascular bed increases intestinal motility. It is suggested that this increased motility might be due to a supression of intrinsic nervous inhibition.

Methods. Experiments were performed on 10 cats weighing 2.0–3.8 kg and fasted for 24 h. Anesthesia was induced by ether followed by i.v. chloralose (50–60 mg/kg body wt.). Arterial pressure was recorded via a femoral artery cannula, and the left and right splanchnic nerves were sectioned. In some experiments all nerves running along the superior mesenteric artery were also cut and placed on a bipolar electrode for distal stimulation. A section of jejunum and its lymph nodes, together weighing 15–25 g, were placed in situ into a lucite chamber containing Tyrodes solution maintained at 38°C, and the rest of the intestine was removed. Venous outflow was recorded by means of an optical drop counter and jejunal motility as intraluminal pressure changes via an open-tipped saline filled cannula, both ends of the segment being tied. The following drugs were injected into the superior mesenteric artery via one of its small branches: 0.2–0.5 mg/kg body wt. atropine sulfate (6 cats), 2–6 µg/kg tetrodotoxin (3 cats), 10–20 mg/kg lidocaine chloride-Xylocaine, Astra (8 cats), and 10–20 mg/kg procaine hydrochloride (1 cat).

Results. Intraarterial tetrodotoxin, lidocaine, and procaine consistently induced an increase in rhythmic intestinal motility after a latency of 1–5 min and lasting up to 30 min, depending on the amount of drug given

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