Newman's lemma

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[synonym element/-s] [synonym system/-s] [synonym reduct/-s]

Signature 1. An element is a notion.

Signature 2. A rewriting system is a notion.

Let $a, b, c, d, u, v, w, x, y, z$ denote elements.
Let R denote a rewriting system.

Signature 3. (Reduct) A reduct of x in R is an element.

Let $x \to_R y$ stand for y is a reduct of x in R.

Signature 4. $x \to_R^+ y$ is a relation.

Axiom 5. $x \to_R^+ y$ iff $x \to_R y$ or there exists an element z such that $x \to_R z \to_R^+ y$.

Axiom 6. If $x \to_R^+ y \to_R^+ z$ then $x \to_R^+ z$.

Definition 7. $x \to_R^* y$ iff $x = y$ or $x \to_R^+ y$.

Lemma 8. If $x \to_R^* y \to_R^* z$ then $x \to_R^* z$.

Definition 9. R is confluent iff for all a, b, c such that $a \to_R^* b, c$ there exists d such that $b, c \to_R^* d$.

Definition 10. R is locally confluent iff for all a, b, c such that $a \to_R b, c$ there exists d such that $b, c \to_R^* d$.

Definition 11. (Terminating) R is terminating iff for all a, b such that $a \to_R^+ b$ we have $b \prec a$.

Definition 12. A normal form of x in R is an element y such that $x \to_R^* y$ and y has no reducts in R.

Lemma 13. Let R be a terminating rewriting system. Every element x has a normal form in R.

Proof. Proof by induction. $\square$

Lemma 14. (Newman) Every locally confluent terminating rewriting system is confluent.

Proof. Let R be a rewriting system. Assume R is locally confluent and terminating.

Let us demonstrate by induction that for all a, b, c such that $a \to_R^* b, c$ there exists d such that $b, c \to_R^* d$. Let a, b, c be elements. Assume $a \to_R^+ b, c$.

Take u such that $a \to_R u \to_R^* b$. Take v such that $a \to_R v \to_R^* c$. Take w such that $u, v \to_R^* w$. Take a normal form d of w in R.

$b \to_R^* d$. Indeed take x such that $b, d \to_R^* x$. $c \to_R^* d$. Indeed take y such that $c, d \to_R^* y$. end. $\square$