JOURNAL OF VIROLOGY, Feb. 1979, p. 501-506
0022-538X/79/02-0501/06$02.00/0

Vol. 29, No. 2

Genes Controlling Receptors for Ecotropic and Xenotropic Type C Virus in *Mus cervicolor* and *Mus musculus*

THOMAS H. MARSHALL AND ULF R. RAPP*

Laboratory of Viral Carcinogenesis, National Cancer Institute, Bethesda, Maryland 20014

Received for publication 7 July 1978

Gene loci controlling cell surface receptors for murine leukemia virus were studied by using murine × Chinese hamster hybrid cells. Hybrids which exclusively segregate murine chromosomes were made by fusing *Mus cervicolor* and *Mus musculus* lymphocytes to hamster fibroblasts. Sensitivity to Moloney murine leukemia virus infection and specific binding of the envelope glycoprotein of Rauscher murine leukemia virus (gp70) cosegregate and isozyme analysis show an association with chromosome 5 in both species. With the possible exception of one clone, no evidence was found for a proviral integration site independent of chromosome 5. Evidence is presented for additional unlinked ecotropic and xenotropic receptors independent of chromosome 5.

The availability of cell surface receptors is necessary for infection and malignant transformation by type C tumor viruses. We (4) and others (7) have previously shown in vivo that receptors for the envelope glycoprotein of murine leukemia virus (MuLV) (gp70) are restricted to lymphoid (7) and lymphoid and brain (4) tissues. The envelope glycoprotein itself may be selectively expressed in different tissues independent of overt virus infection (16, 19, 24). Thus, two type C virus-related genes, those for the envelope glycoprotein and its corresponding receptor, are expressed in a tissue-specific manner, possibly reflecting a physiological role for type C virus genes in modulating tissue-specific cell-cell interactions.

Endogenous type C viruses of *Mus* can be classified on the basis of antigenic and nucleic acid sequence homology as class CI, examples of which have been isolated from *Mus caroli* and *M. cervicolor*, and class CII, which include all endogenous viruses of *Mus musculus* as well as certain isolates from *M. cervicolor* (1). The CII class includes viruses of both ecotropic and xenotropic host ranges. The latter do not normally replicate in *M. musculus* fibroblasts, and studies involving phenotypically mixed viruses indicate that this restriction, as well as that of ecotropic viruses in heterologous cells, is predominantly at the cell surface (3, 12). Specific binding of Rauscher gp70 to ecotropic receptors in *M. musculus* fibroblasts has been demonstrated previously in this laboratory, showing that heterologous cells lack receptors for ecotropic MuLV (5).

Mouse × hamster hybrid cells are well suited to study murine genes controlling replication of MuLV (20). It was shown that passage of Rauscher MuLV in mouse × hamster hybrid cells did not alter its host range or focus-forming properties on S+L− cells (20). In the present report we describe the infection of hybrid cells with three class CII type C viruses, two ecotropic and one xenotropic in host range. In addition we find that radiolabeled Rauscher gp70 binding corresponds with susceptibility to Moloney MuLV infection, indicating that genes controlling receptor expression are controlling susceptibility to virus infection in the hybrids. This gene is assigned to mouse chromosome 5. Previously a gene controlling virus replication was assigned to chromosome 5 in *M. musculus* (8, 22). Evidence for additional unlinked genes controlling specific ecotropic and xenotropic receptors is presented in this report.

MATERIALS AND METHODS

Culture media. Cells were grown in Dulbecco-modified Eagle medium containing 10% fetal calf serum (DMEM) and passaged by trypsinization. Hybrid cells were grown in DMEM supplemented with hypoxanthine, aminopterin, and thymidine (HAT).

Cell fusion. A cell suspension was obtained from a spleen which had been removed asceptically from a 3-month-old male *M. cervicolor*. Splenocytes and Chinese hamster fibroblasts were washed three times in serum-free DMEM salts, and 7×10^6 of each were combined in 4 ml of a fusion cocktail containing 200 hemagglutination units of β-proprionyl lactone-inactivated Sendai virus per ml and 5 μg of DNase I (Worthington) per ml in serum-free DMEM. The fusion mixture was incubated on ice for 15 min and then for 5 h at 37°C, after which it was plated in DMEM. Twenty hours later the fusion mixture was plated at low density in HAT. Media were changed every 3 days, and colonies of hybrid cells were transferred to mass culture with the aid of cloning cylinders approx-

imately 3 weeks postfusion. *M. musculus* × Chinese hamster hybrids were made similarly with thymus as well as spleen tissues of strain 129 and congenic B6 GIX$^+$ (23) mice.

Viruses. Moloney MuLV was passaged on C3H and MJD-54 (13) mouse cells for infection of *M. musculus* and *M. cervicolor* × Chinese hamster hybrids, respectively. M813 is a class CII isolate from *M. cervicolor popaeus* spleen tissue (R. Callahan, unpublished data). Mol/8155, a spontaneous isolate from *M. musculus molossinus* (18), was passaged on dog thymus cells.

Virus infection. Cells (3×10^5) were plated in 75-cm^2 tissue culture flasks. One day later the cultures (including controls) were treated for 1 h with 8 μg of Polybrene per ml, which was removed, and 1 ml of virus suspension was inoculated. Inoculated cultures were incubated at 37°C for 3 h, and 15 ml of medium was added. M813 and Mol/8155 viruses were concentrated for infection by pelleting asceptically 125 ml of culture fluid through a sucrose cushion and resuspending in 23 ml of serum-free DMEM salts. Culture fluid from Moloney MuLV-producing cells was filtered and inoculated directly.

Reverse transcriptase assay. Twenty-four hour medium harvests were taken from late-log-phase cultures for supernatant reverse transcriptase assay. The assay mixture used a polyriboadenylate template and oligodeoxythymidylate primer (25).

Isozyme analysis. Soluble extracts were prepared for isozyme analysis by washing confluent cultures with phosphate-buffered saline, scraping, and suspending cells in a phosphate buffer, pH 6.8, followed by sonic disruption. Sonic extracts were centrifuged 30 min at 50,000 × *g* at 4°C and the supernatant stored at −70°C. Isozyme analysis was performed by vertical starch gel electrophoresis and histochemical staining by standard methods (21). Extracts of Chinese hamster E36 and *M. cervicolor* and *M. musculus* cells were included as controls. The following isozymes were determined: dipeptidase 1 (EC 3.4.13.11), phosphoglucomutase-2 (PGM-2, EC 2.7.5.1), PGM-1 (EC 2.7.5.1), 6-phosphoglucomate dehydrogenase (EC 1.1.1.44), glucosephosphate isomerase (EC 5.3.1.9), mannosephosphate isomerase (EC 5.3.1.8), purine-nucleoside phosphorylase (EC 2.4.2.1), tripeptidase-1 (EC 3.4.11), dipeptidase-2 (EC 3.4.11), adenine phosphoribosyltransferase (EC 2.4.2.7), acid phosphatase (EC 3.1.3.2), adenylate kinase (EC 2.7.4.3), Di-peptidase-D (EC 3.4.11.9) and hypoxanthine phosphoribosyltransferase (EC 2.4.2.8), Glyoxylase-1 (EC 4.4.1.5), triosephosphate Isomerase (EC 5.3.1.1), galactokinase (EC 2.7.1.6), glutathione reductase (EC 1.6.4.2), and malic enzyme (EC 1.1.1.40).

RESULTS

Characterization of hybrid cells. E36 Chinese hamster fibroblasts do not survive in HAT medium because they are hypoxanthine phosphoribosyltransferase deficient (9). Spleen cells do not proliferate efficiently or adhere to the tissue culture dish. After 3 weeks the only adhering cells are hybrid colonies which replicate efficiently upon transfer to mass culture. Isozyme analysis shows variable extents of *M. cervicolor* chromosome segregation and complete retention of Chinese hamster chromosomes. Heteropolymeric bands in addition to parental bands confirm their hybrid nature.

Most of the isozyme markers of murine chromosomes which can be used in *M. musculus* × Chinese hamster hybrids can be resolved in *M. cervivolor* × Chinese hamster hybrids. We have evidence that specific murine structural gene linkages are preserved in these species of *Mus* which diverged approximately 4 million years ago (1). The diploid number and chromosome morphology are indistinguishable, as are the fluorescent banding patterns along the length of the chromosome, excepting the centromere, indicating that gross rearrangements have not occurred since the two species diverged (6). It is probable that the majority of gene linkages are shared between these two species, and thus we may tentatively assume that a given isozyme marks homologous chromosomes in *M. cervicolor* and *M. musculus*.

Host range of viruses used to infect *M. cervicolor* × Chinese hamster hybrids. Ecotropic type C viruses infect murine cells but not those of other species, whereas xenotropic viruses infect other species but not murine cells (2, 17). Table 1 shows the host range of Moloney, M813, and Mol/8155 MuLV stocks used to infect *M. cervicolor* × Chinese hamster hybrid cells. Moloney and M813 show typical ecotropic host range, whereas Mol/8155 shows xenotropic host range.

Infection of *M. cervicolor* × Chinese hamster hybrid cells. We infected *M. cervicolor* × Chinese hamster hybrids with Moloney, M813, and Mol/8155 viruses. Infected cultures were split 1 to 10 and assayed weekly for viral reverse transcriptase. Virus-sensitive Moloney- and M813-infected cultures showed supernatant reverse transcriptase activity within 2 weeks. Sensitive Mol/8155-infected cultures showed supernatant reverse transcriptase by week 5. Mol/8155-infected cultures producing no supernatant reverse transcriptase were carried and assayed for 8 weeks postinfection. Mock-infected controls produced no supernatant reverse transcriptase.

TABLE 1. *Host range of viruses used to infect murine × Chinese hamster hybrids*

Species	MuLv		
	Moloney	M813	Mol/8155
M. musculus	+	+	−
M. cervicolor	+	+	+
Chinese hamster	−	−	−
Cat	−	−	+

Sensitivity to infection by the three viruses segregates independently in the hybrids; 9, 14, and 6 of the 17 hybrid clones are sensitive to infection by Moloney, M813, and Mol/8155, respectively (Table 2). Several hybrids (C36, 8, 9, 15, and 16) are sensitive to all three viruses, whereas C36 2, 3, and 13 are sensitive to none. Significantly, the latter are very highly segregated for *M. cervicolor* chromosomes, whereas the former are much less so. Again this suggests that differences in sensitivity to infection in the hybrids are due to differential segregation of *M. cervicolor* chromosomes coding for cell surface receptors. If sensitive hybrids resulted from segregation of internal restriction gene(s), we would expect sensitivity to infection to be found in more highly rather than less highly segregated hybrids.

No virus replicates in every hybrid infected. This implies that no chromosome which is retained in every hybrid could code for a gene product, such as a receptor, which uniquely determines sensitivity in the hybrids. The HAT selective system causes retention of the *M. cervicolor* "X" chromosome. Thus, it may be concluded that the X chromosome does not uniquely determine sensitivity to MuLV infection in these hybrids.

gp70 Binding to *M. cervicolor* × Chinese hamster hybrid cells. Binding studies were performed with radiolabeled Rauscher glycoprotein (gp70) on hybrid cell cultures at the same passage level at which they were infected with Moloney, M813, and Mol/8155 viruses. Table 3 shows that gp70 binding and sensitivity to Moloney MuLV cosegregate. This implies that the gp70 binding site and Moloney receptor are genetically as well as physically (5) linked and further confirms that sensitivity to Moloney MuLV infection in the hybrids is controlled by surface receptors.

Isozyme analysis provides specific markers for segregating *M. cervicolor* chromosomes. Thus, it may be possible to assign receptor genes to specific chromosomes based on synteny with particular *M. cervicolor* isozymes. Our data (Table 3) show synteny between the Moloney MuLV-Rauscher gp70 receptor and PGM-1 (phosphoglucomutase-1). PGM-1 is assigned to chromosome 5 in *M. musculus* (11). We have found that certain gene linkages are conserved in *M. musculus* and *M. cervicolor* (data not shown). This is not surprising for these related species of *Mus*. Thus, we can tentatively conclude that for this *cervicolor* mouse the Moloney MuLV receptor is controlled by a gene on chromosome 5.

Table 4 shows each isozyme tested, its extent of segregation, and asynteny with the virus receptors. PGM-1 is unique in its synteny with the Moloney virus receptor. No other isozyme is syntenic with it, and PGM-1 is asyntenic with receptors for the other two viruses.

Infection of and gp70 binding to *M. musculus* × Chinese hamster hybrid cells. Similar experiments were designed to study the Mo-

TABLE 2. *Sensitivity to infection of M. cervicolor × hamster hybrid cells*[a]

Hybrid clone	MuLV			Autosomal isozymes retained[b]
	Moloney	M813	Mol/8155	
C36 1	−	+++	−	7/12
2	−	−	−	0/12
3	−	−	−	2/12
4	−	+++	++	7/12
5	+++	+++	−	6/12
6	+++	+++	+	11/12
7	−	+	−	1/12
8	+++	+++	++	8/12
9	+++	+++	+	5/12
11	+++	++	−	6/12
13	−	−	−	0/12
14	−	++	−	7/12
15	+++	+++	+	11/12
16	++	+++	+	10/11
19	+++	+++	−	6/12
20	−	+	−	5/12
21	+++	++	−	9/12

[a] Supernatant reverse transcriptase of infected cultures: +, 20,000 to 35,000 cpm; ++, 35,000 to 100,000 cpm; +++, over 100,000 cpm. Uninfected controls showed less than 10,000 cpm.

[b] Fraction of murine autosomally linked isozymes retained/total tested.

TABLE 3. *Moloney MuLV replication, gp70 binding, and chromosome 5 marker in M. cervicolor × hamster hybrid cells*

Hybrid clone	Replication[a]	gp70 Binding[b]	PGM-1
C36 1	−	1.89	−
2	−	1.53	−
3	−	0.95	−
4	−	1.30	−
5	+++	17.4	+
6	+++	32.0	+
7	NT	1.02	−
8	+++	24.1	+
9	+++	16.2	+
11	+++	25.3	+
13	−	0.26	−
14	−	1.46	−
15	+++	47.4	+
16	++	54.4	+
19	+++	31.9	+
20	−	2.54	−
21	+++	49.3	+

[a] Scoring the same as Table 2. NT, Not tested.

[b] Femtomoles bound per 10^6 cells. E36 and NIH cells bound 2.20 and 34.5 fmol, respectively.

TABLE 4. *Retention of M. cervicolor isozymes in cervicolor × hamster hybrid cells and their asynteny with Moloney MuLV receptor*

Isozyme (murine chromosome)	Fraction of hybrids retaining	Fraction asyntenic with receptor
Dipeptidase-1 (1)	8/16	2/16
Adenylate kinase-1 (2)	5/17	8/17
6-Phosphogluconate dehydrogenase (4)	8/17	9/17
Phosphoglucomutase-2 (4)	8/17	9/17
Phosphoglucomutase-1 (5)	9/17	0/17
Glucosephosphate isomerase (7)	11/17	4/17
Dipeptidase-D (7)	11/17	4/17
Adenine phosphoribosyltransferase (8)	7/17	6/17
Glutathione reductase (8)	7/17	6/17
Malic enzyme (9)	12/17	3/17
Tripeptidase-1 (10)	9/17	2/17
Galactokinase (11)	0/17	9/17
Purine nucleoside phosphorylase (14)	6/17	9/17
Glyoxylase-1 (17)	8/15	1/15
Dipeptidase-2 (18)	8/17	8/17
Hypoxanthine phosphoribosyltransferase	17/17	8/17

loney MuLV receptor in *M. musculus*. Spleen cells of strain 129 and spleen and thymus of congenic B6 GIX$^+$ mice were fused to Chinese hamster fibroblasts. Hybrid clones were selected in HAT media. Their properties were very similar to *M. cervicolor* × hamster hybrids described above. Isozyme analysis showed they retained Chinese hamster and segregated mouse chromosomes.

We measured specific binding of radiolabeled Rauscher glycoprotein (gp70) to *M. musculus* × hamster hybrid cells. Separate cultures were infected at the same passage level with Moloney MuLV and assayed weekly for viral reverse transcriptase. At 3 weeks postinfection they were seeded for XC infectious center assay. Mock-infected control cultures produced no supernatant reverse transcriptase activity.

Table 5 shows that sensitivity to Moloney MuLV infection correlates with gp70 binding. This implies that gp70 binding detects functional virus receptors and that sensitivity to virus infection in the hybrids depends only on available cell surface receptors. Of 37 *M. musculus* hybrids, 20 expressed Moloney MuLV receptors. Mouse PGM-1 is expressed in the hybrids which express receptors for Moloney MuLV, including two which had segregated all other isozymes tested (CTE7, CTE22; Table 5). Hybrids which did not express mouse PGM-1 did not express the receptor, including 12E6 which retained 10 of 11 tested isozymes (Table 5).

Table 6 shows the other mouse isozymes tested, their chromosomal assignments, and degrees of retention and asynteny with the Moloney MuLV receptor. Of those isozymes tested, PGM-1 is unique in being syntenic with the

TABLE 5. *Moloney MuLV replication and isozyme characteristics of hamster × M. musculus hybrid cells*

Hybrid clone	gp70 Bound[a]	RT[b]	XC[c]	PGM-1 (chromosome 5)	Fraction of mouse isozymes retained
B6 GIX$^+$ spleen					
CSE4	0.43	−	NT[d]	−	4/10
CSE5	8.77	+	>10^3	+	9/11
CSE8	0.72	−	NT	−	1/9
CSE9	0.76	−	4	−	3/11
CSE13	0.89	−	−	−	6/11
CSE17	20.3	+	204	+	9/11
CSE18	22.7	++	>300	+	7/11
CSE21	0.52	−	NT	−	3/10
CSE25	22.7	+++	NT	+	6/8
CSE26	1.61	−	NT	−	2/8
CSE27	12.3	+	>10^3	+	7/11
B6 GIX$^+$ thymus					
CTE2	8.79	++	>300	+	4/11
CTE6	21.4	+++	NT	NT	8/8
CTE7	13.8	++	NT	+	1/8
CTE8	26.3	++	>10^3	+	8/11
CTE9	21.3	++	>10^3	+	4/11
CTE10	0.34	−	NT	−	1/8
CTE13	0.74	−	2	−	1/9
CTE16	10.2	++	NT	+	7/8
CTE17	0.53	NT	−	−	5/10
CTE20	1.08	−	NT	−	5/10
CTE21	1.62	−	NT	−	5/8
CTE22	10.05	+	NT	+	1/8
CTE24	4.2	−	76	+	6/11
CTE28	0.87	−	NT	−	2/11
129 Spleen					
12E2	8.42	++	NT	+	7/7
12E5	11.3	++	>500	+	9/10
12E6	0.51	−	11	−	10/11
12E7	10.2	++	>500	+	9/11
12E15	0.27	−	1	−	7/10
12E17	10.4	+++	NT	+	9/10
12E18	7.75	+++	>10^3	+	7/10
12E20	14.2	+	96	+	10/11
12E22	1.32	−	−	−	3/11
12E23	0.54	−	NT	−	2/10
12E24	6.54	++	>10^3	+	6/9
12E28	0.90	−	NT	−	5/10

[a] Femtomoles of [^{125}I]gp70 bound per 10^6 cells. Binding of radioiodinated gp70 to mouse A31 control cells, which bind 32.2 fmol/10^6, is reduced to 0.5 in the presence of native gp70. Similar reduction occurs with hybrid cells expressing receptor. E36 cells bind a maximum of 1.3 fmol/10^6.

[b] RT, Viral reverse transcriptase activity. Uninfected controls produced 3,000 to 10,000 cpm. Infected hybrids are scored: <20,000 (−); 20,000 to 100,000 (+); 100,000 to 500,000 (++); over 500,000 (+++).

[c] XC, Infectious center assay. XC plaques per 10^5 cells.

[d] NT, Not tested.

TABLE 6. *Retention of mouse isozymes in Musculus × hamster hybrid cells and asynteny with virus receptor*

Isozyme (chromosome)	% Hybrid clones retaining isozyme	% Asyntenic with Virus Receptor
Dipeptidase-1 (1)	59	45
Adenylate kinase (2)	43	23
Phosphoglucomutase-2 (4)	40	29
6-Phosphogluconate dehydrogenase (4)	42	34
Phosphoglucomutase-1 (5)	54	0
Triosephosphate isomerase (6)	23	33
Dipeptidase-D (7)	60	28
Glucosephosphate isomerase (7)	60	28
Adenine phosphoribosyltransferase (8)	42	44
Mannosephosphate isomerase (9)	50	33
Malic enzyme (9)	47	29
Tripeptidase-1 (10)	55	33
Galactokinase (11)	0	53
Acid phosphatase (12)	56	12
Purine nucleoside phosphorylase (14)	49	56
Glyoxylase-1 (17)	68	27
Dipeptidase-2 (18)	59	78
Hypoxanthine phosphoribosyltransferase (X)	100	47

receptor. PGM-1 has been assigned to chromosome 5 (11).

Of all the *M. musculus* × Chinese hamster hybrids examined, CTE24 (Table 5) requires special comment. It expresses mouse PGM-1 and a low but definite level of gp70 binding. It showed no supernatant reverse transcriptase upon infection with Moloney MuLV. The XC infectious center assay detects a small fraction of virus-producing cells. This discordancy between receptor expression and its genetic locus on the one hand and virus replication as measured by reverse transcriptase on the other might suggest that this clone is a heterogeneous population of cells undergoing continuous segregation of chromosome 5. The gp70 binding assay may be more sensitive in detecting low levels of receptor expression than is infection followed by reverse transcriptase assay. This explanation is favored by the fact that CTE24 binds less gp70 than any other hybrid which expresses mouse PGM-1, the isozyme marker of chromosome 5. However, the fact that the same discordancy was observed when this clone was examined several passages later suggests that it is not heterogeneous due to chromosome segregation. If CTE24 is homogeneous, the discordancy could conceivably be due to the absence of a second chromosomal locus required for efficient replication. Such a locus could be a proviral integration site.

DISCUSSION

We have studied chromosomal loci which control cell surface receptors for three type C viruses in murine × Chinese hamster hybrid cells. Moloney MuLV replicates in all *M. musculus* and *M. cervicolor* hybrids which express receptors for Rauscher gp70 as determined by binding assay. Isozyme analysis reveals that the gene controlling gp70 binding and Moloney MuLV infection resides on chromosome 5 in both species. The data show no evidence for a second genetic locus required for Moloney MuLV replication, i.e., every hybrid which expressed the receptor as determined by gp70 binding assay replicated virus. Proviral integration is presumably required for replication in hybrid cells. The fact that the receptor correlates with replication might suggest that a potential integration site is genetically linked to the receptor on chromosome 5. Alternatively, the provirus could integrate preferentially at a second murine chromosomal site or nonspecifically in the murine or hamster genome. Recently, human chromosome 6 was identified as necessary for baboon MuLV replication in rodent × human hybrid cells (15). The available evidence indicates that this is a proviral integration site (14).

Our data show that in *M. cervicolor* susceptibility to M813 and Mol/8155 infection segregate independently from each other and from chromosome 5. Direct gp70 binding assay for surface receptors shows that susceptibility to Moloney MuLV infection of murine × Chinese hamster hybrid cells is strictly a matter of cell surface receptors. It is highly probable that M813 and Mol/8155 infection similarly depends only on expression of their respective receptors. M813 and Mol/8155 are ecotropic and xenotropic, respectively, in host range. Thus, our data imply that *M. cervicolor* has a minimum of two unlinked genes for ecotropic receptors as well as a third independently segregating gene for a xenotropic receptor. At least one of these ecotropic receptors and its genetic locus are conserved between *M. cervicolor* and *M. musculus*.

Multiple viral receptors, each with its own specificity, may be capable of interacting with a variety of normal and defective viral gene products. Virus-related genetic information exists in multiple copies in most if not all mammalian tissue. ENV gene products may be expressed in a tissue specific manner (16, 19, 24). Processing errors may result in accumulation of normal or

defective viral proteins or their precursors in the cell membrane. Specific interaction between receptors in one cell and viral gene products in another cell could provide a basis for cellular recognition and organization in normal and pathological processes.

Previously, a low level of sensitivity to xenotropic MuLV was reported in a cell line derived from a feral mouse which lacked Fv-1 restriction, leading to the suggestion that xenotropic restriction may be partially of the Fv-1 type (10). Our data show that Mol/8155 restriction segregates independently of chromosome 4, the site of the Fv-1 locus.

ACKNOWLEDGMENTS

This work was supported in part by the Virus Cancer Program of the National Cancer Institute.

We thank Joe De Larco for radiolabeled Rauscher gp70, Mindy Davis Goldsborough for excellent technical assistance, and Robert Callahan and George J. Todaro for helpful discussions. The congenic B6 GIX$^+$ mice were kindly provided by E. A. Boyse.

LITERATURE CITED

1. **Benveniste, R., R. Callahan, C. Sherr, V. Chapman, and G. J. Todaro.** 1977. Two distinct endogenous type C viruses isolated from the Asian rodent *Mus cervicolor*: conservation of virogene sequences in related rodent species. J. Virol. **21**:849–862.
2. **Benveniste, R., M. Lieber, and G. J. Todaro.** 1974. A distinct class of inducible murine type C viruses that replicate in the rabbit SIRC cell line. Proc. Natl. Acad. Sci. U.S.A. **71**:602–606.
3. **Besmer, P., and D. Baltimore.** 1977. Mechanism of restriction of ecotropic and xenotropic murine leukemia viruses and formation of pseudotypes between the two viruses. J. Virol. **21**:965–973.
4. **De Larco, J. E., U. R. Rapp, and G. J. Todaro.** 1978. Cell surface receptors for ecotropic MuLV: detection and tissue distribution of free receptors *in vitro*. Int. J. Cancer **21**:356–360.
5. **De Larco, J. E., and G. J. Todaro.** 1976. Membrane receptors for murine leukemia viruses: characterization using the purified viral envelope glycoprotein gp71. Cell **8**:365–371.
6. **Dev, V., D. Miller, O. Miller, and J. Marshall.** 1973. Quinacrine fluorescence of Mus cervicolor chromosomes, bright centromeric heterochromatin. Exp. Cell Res. **79**:475–478.
7. **Fowler, A. K., D. R. Twardzik, C. D. Reed, O. S. Weislow, and A. Hellman.** 1977. Binding characteristics of Rauscher leukemia virus envelope glycoprotein gp71 to murine lymphoid cells. J. Virol. **24**:729–735.
8. **Gazdar, A., H. Oie, P. Lalley, W. Moss, J. Minna, and U. Francke.** 1977. Identification of mouse chromosomes required for Murine leukemia virus replication. Cell **11**:949–956.
9. **Gillin, F., D. Roufa, A. Beaudet, and C. T. Caskey.** 1972. 8-Azaguanine resistance in mammalian cells. I. Hypoxanthine—guanine phosphoribosyltransferase. Genetics **72**:239–252.
10. **Hartley, J. W., and W. P. Rowe.** 1975. Clonal cell lines from a feral mouse embryo which lack host-range restrictions for murine leukemia viruses. Virology **65**: 128–134.
11. **Hutton, J. J., and T. H. Roderick.** 1970. Linkage analysis using biochemical variants in mice III linkage relationship of eleven biochemical markers. Biochem. Genet. **4**:339–350.
12. **Ishimoto, A., J. W. Hartley, and W. Rowe.** 1977. Detection and quantitation of phenotypically mixed viruses: mixing of ecotropic and xenotropic murine leukemia viruses. Virology **81**:263–269.
13. **Leamnson, R., M. Shander, and M. Halpern.** 1977. A structural protein complex in Moloney leukemia virus. Virology **76**:437–439.
14. **Lemons, R. S., W. G. Nash, S. J. O'Brien, R. E. Benveniste, and C. J. Sherr.** 1978. A gene *Bevi* on human chromosome six is a preferred integration site for baboon type C DNA provirus in human cells. Cell **14**:995–1005.
15. **Lemons, R. S., S. J. O'Brien, and C. J. Sherr.** 1977. A new genetic locus, *Bevi*, on human chromosome six which controls the replication of baboon type C virus. Cell **12**:251–262.
16. **Lerner, R. A., B. W. Curtis, B. C. Del Villano, P. J. McConahey, and F. J. Dixon.** 1976. Endogenous oncornaviral gene expression in adult and fetal mice: quantitative, histological, and physiologic studies of the major viral glycoprotein, gp70. J. Exp. Med. **143**:151–165.
17. **Levy, J. A.** 1973. Xenotropic viruses: murine leukemia viruses associated with NIH Swiss, NZB, and other mouse strains. Science **182**:1151–1153.
18. **Lieber, M., C. J. Sherr, M. Potter, and G. J. Todaro.** 1975. Isolation of type C viruses from the Asian feral mouse *Mus Musculus Molossinus*. Int. J. Cancer **15**: 211–220.
19. **McClintock, P. R., J. N. Ihle, and D. R. Joseph.** 1977. Expression of AKR Murine leukemia virus gp71-like and BALB(X) gp71-like antigens in normal mouse tissues in the absence of overt virus expression. J. Exp. Med. **146**:422–434.
20. **Marshall, T. H., A. Gazdar, and J. D. Minna.** 1975. Replication of Murine leukemia virus in chinese hamster X mouse hybrid cells: lack of association with FV-1 locus. J. Cell. Biol. **67**:262a.
21. **Nichols, E., and F. Ruddle.** 1973. A review of enzyme polymorphism, linkage and electrophoretic conditions for mouse and somatic cell hybrids in starch gels. Histochemistry **21**:1066–1081.
22. **Oie, H. K., A. F. Gazdar, P. A. Lalley, E. K. Russell, J. D. Minna, J. De Larco, G. J. Todaro, and U. Franke.** 1978. Mouse chromosome 5 codes for ecotropic murine leukemia virus cell-surface receptor. Nature (London) **274**:60–62.
23. **Stockert, E., E. A. Boyse, Y. Obatta, H. Ikeda, N. Sarkar, and H. Hoffman.** 1975. New mutant and congenic mouse stocks expressing the murine leukemia virus-associated thymocyte surface antigen GIX. J. Exp. Med. **142**:512–517.
24. **Strand, M., J. T. August, and R. Jaenisch.** 1977. Oncorna virus gene expression during embryonal development of the mouse. Virology **76**:886–890.
25. **Todaro, G., S. Tevethia, and J. Melnick.** 1973. Isolation of an RD-114 related type C virus from feline sarcoma virus-transformed baboon cells. Intervirology **1**: 399–404.